UKRAINE'S TECHNOLOGY SECTOR

A Report Prepared by the Federal Research Division,
Library of Congress
under an Interagency Agreement with the
Director of Defense Research and Engineering,
Office of the Secretary of Defense

October 2008

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1948 – 2008

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
OCT 2008		**00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Ukrain's Technology Sector	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Federal Research Division,Library of Congress,Washington,DC,20540-4840**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**119**	

PREFACE

This study provides a general assessment of major science and technology (S&T) developments in Ukraine. The report is organized into eight sections: key findings, an economic and political overview of Ukraine, a description of Ukraine's technology sector, Ukraine's science policy, the country's research and development (R&D) resources, brief profiles of Ukraine's main technology sectors, Ukraine's participation in international S&T, and a conclusion. The Appendices list prominent Ukrainian research facilities and their respective specialties.

The author used English-, Russian-, and Ukrainian-language sources in the research for this report. Whenever possible, this study relied on primary-source documents published by the Ukrainian government, including the Ukraine Ministry of Foreign Affairs, Academy of Sciences, Parliament, State Statistical Committee, and Ministry of Education and Science. Writings by specialists at the Science and Technology Center of Ukraine (STCU) have proved very fruitful, though sometimes difficult to access through the STCU portal. The Ukrainian embassy in Washington, DC, provided a report entitled "A Science Profile of Ukraine," which contained a great deal of background material on the Ukrainian S&T sector unavailable elsewhere. Other documents used in this study include reports by non-Ukrainian government agencies (such as U.S. government agencies), intergovernmental organizations, and the Ukrainian and other media. The author obtained all the documents used in this study from the collections and databases at the Library of Congress, including Eastview, Intelink, ISI Emerging Markets, Jane's Information Group, Lexis-Nexis, and the Open Source Center as well as the Internet.

For the purposes of this study, S&T includes all scientific study and experimentation directed toward increasing fundamental knowledge and understanding in the physical, engineering, environmental, and life sciences, and the systematic expansion and application of the knowledge to develop useful materials, devices, systems, and methods. R&D includes the elements of S&T defined above, plus efforts to evaluate integrated technologies, representative modes, or prototype systems in a high-fidelity, realistic operating environment, along with the associated engineering and manufacturing development tasks necessary for production.

TABLE OF CONTENTS

PREFACE i

KEY FINDINGS 1

INTRODUCTION 5

ECONOMIC AND POLITICAL OVERVIEW 6

UKRAINE'S S&T SECTOR 8
- Under the Soviet Union 8
- Changes in the 1990s 9
- Ukrainian S&T Since 2000 11

UKRAINE'S S&T POLICY 12
- Institutions Involved in Setting S&T Policy 12
  - *President and Cabinet of Ministers* 12
  - *Supreme Council* 13
  - *Ministry of Education and Science* 13
- Legislation Governing the S&T Sector 16

UKRAINE'S R&D RESOURCES 19
- R&D Funding 20
  - *R&D Funding as a Percentage of GDP/GNP* 22
  - *Financing Sources for R&D* 23
  - *Public versus Private Financing* 24
  - *Funding by Types of R&D* 26
  - *R&D Spending by S&T Sector* 26
  - *The Banking Sector* 27
  - *Government Incentive Programs Promoting R&D* 28
  - *Foreign Direct Investment in R&D* 29
- The S&T Workforce 30
  - *Ukraine's Brain Drain* 32
  - *The Age Crisis in the S&T Sector* 33
  - *Joint Programs to Employ Former WMD Scientists* 34
- Capital and Information Assets 37
- Research Organizations 38
  - *System of State Academies* 39
  - *Institutes of Higher Education* 43
  - *Technoparks* 43

TECHNOLOGIES 45
- Fuel and Energy Technologies 45
- Nanotechnologies 47
- Biotechnologies 49

Agriculture 50
Medicine 50
Weapons 52
Chemical Industry 54
Information and Communications Technology 55
Military Technologies 57
Sensors 59
Missiles 61
Aviation 63
Nuclear Sector 66
Fuel 66
Power 68
Weapons 71
International Cooperation 71
Research 73
Space 73

UKRAINE'S PARTICIPATION IN INTERNATIONAL S&T 79
Technology Transfer 80
Licensing 82
R&D Relations with Other Countries 83
European Union and NATO 83
Russia 85
United States 86

CONCLUSION 87

BIBLIOGRAPHY 91

APPENDIX A. TECHNOPARKS IN UKRAINE 101

APPENDIX B. LEADING UKRAINIAN NANOTECHNOLOGY RESEARCH ORGANIZATIONS 103

APPENDIX C. LEADING UKRAINIAN BIOTECHNOLOGY RESEARCH ORGANIZATIONS 105

APPENDIX D. LEADING UKRAINIAN CHEMICAL RESEARCH ORGANIZATIONS 109

APPENDIX E. LEADING UKRAINIAN SENSOR RESEARCH ORGANIZATIONS 111

APPENDIX F. LEADING UKRAINIAN AVIATION RESEARCH ORGANIZATIONS 113

APPENDIX G. LEADING UKRAINIAN SPACE-RELATED RESEARCH AND PRODUCTION ORGANIZATIONS 115

FIGURES

Figure 1. Ukraine, Ministry of Education and Science, S&T Departments 15
Figure 2. Comparison of the Knowledge Economy Index (KEI) and its Component Measures for Ukraine, Russia, and the United States, 2008 20
Figure 3. Ukraine: R&D Expenditures 1990–2004 23
Figure 4. Ukraine: Sources of Financing for Technological Innovations, 2000–6 24
Figure 5. R&D Expenditures by Source of Funds 25
Figure 6. R&D Expenditures by Sector of Performance 25
Figure 7. Ukraine: Type of R&D Work Performed, 1996, 2000, 2006 26
Figure 8. Ukraine S&T Funding by Sector, 2001 27
Figure 9. Ukraine: R&D Personnel 1992–2003 31
Figure 10. Funding per Researcher, 2002 31
Figure 11. Economically Active Scientists (Candidates and Doctors of Science) in Ukraine, by Age, 2006 34
Figure 12. Distribution of NASU Funding from NASU State Budget 40
Figure 13. Distribution of NASU Funding from Other Sources 41
Figure 14. Comparison of Internet Hosts, 2006 56
Figure 15. Comparison of Internet Users, 2006 56
Figure 16. Map of Ukraine's Nuclear Power Plant Complexes 69

KEY FINDINGS

- Following the breakup of the Soviet Union, Ukraine fell into an economic crisis that persisted throughout the 1990s. Gross domestic product (GDP) for the period dropped by more than 60 percent, while loose monetary policies led to hyperinflation starting in late 1993. Whole industries virtually disappeared, and domestic demand for many products, especially high-tech products, dropped dramatically.
- Ukraine's economy has shown signs of recovery since 2000. In 2006 GDP was higher than predicted as a result of increased domestic consumption, manufacturing, and construction; rising world steel prices; and internal changes in Ukrainian economic policy, reforms, and institutional development. Nonetheless, in 2007 most government programs, including those related to national R&D policy and the development of science, still lacked cohesion and clear direction.
- After the dissolution of the Soviet Union, Ukraine was unable to maintain its science sector at the same level as under Soviet rule. Drastic funding reductions for science affected the acquisition of state-of-the-art research equipment, the viability of long-term research projects, scientists' salaries, and the prestige of the science and engineering community. The consequence was a gradual reduction in the number of state research establishments and the loss of many scientists to more profitable work within Ukraine or abroad, particularly to Israel, Russia, and the United States.
- One of Ukraine's most important economic activities after gaining independence was the conversion of the military-industrial complex (MIC) to viable commercial activities, with technology playing a key role. As a result of Ukraine's economic growth and the conversion of its MIC to civilian production, both the number of researchers and the amount of R&D funding have stabilized.
- The Ukrainian government's priorities, as governed by the *Law of Ukraine, On Priority Directions of Innovation Activity in Ukraine* No. 433–IV (effective February 13, 2003), sets forth the following strategic medium-term priorities for innovation for the period 2003 to 2013: modernization of power stations; development of new alternative and renewable energy sources; high-tech development of the machine-building, instrument-making, and metallurgy industries; development of nanotechnologies, microelectronics, information technology, and telecommunications; improvement in chemical technologies,

new materials, and biotechnologies; high-tech development of agriculture and the food-processing industry; building and reconstruction of transport systems; improvement of human and environmental health; and development of an innovation culture in Ukrainian society.

- Under Ukraine's current innovation policy, the government plans to exploit technological innovations for the purpose of economic growth. Ukraine has strong research potential in aviation, biochemistry, crystallography, mathematical and computer modeling, and metallurgy, among other fields.
- Ukraine's legal framework for its S&T activities has as its basis the following three major laws, which are regularly updated and amended: *On the Fundamentals of Public Policy in the Sphere of Science and Technology Activities* (December 13, 1991), *On Priority Branches of Science and Technology Development* (August 2, 2001), and *On Priority Directions of Innovation Activity in Ukraine* (February 13, 2003). However, not all of these laws are direct action laws; they have been adopted in a disorganized manner and have proven difficult to implement. Moreover, many organizations have taken advantage of the privileges intended for scientific and innovative organizations, while relatively few of them are prosecuted for their infractions.
- Nearly one-third of Ukrainian R&D specialists, mostly physicists and biologists and specialists from the MIC and the nuclear energy industry, left Ukraine between 1988 and 1992, in search of higher-paid work suited to their background and training in Russia.
- Ukraine has experienced a considerable decline in its public research sector, while its private research sector is established and expanding. Experts share concern about the steadily declining share of government expenditures and the rapidly growing share of foreign funds from the United States, European Union (EU) countries, and Russia supporting Ukraine's R&D.
- Energy security is an important issue in Ukraine. The government expects that, through 2030, Ukraine will experience a major increase in demand for electricity and plans to supply half of it from nuclear power.
- Ukraine technology shows promising development in the fields of nanoelectronics, super-high-speed data transfer, IP-telephony, the creation of light super-durable materials, and heterogeneous surfaces welding. However, despite Ukraine's R&D strengths in these

fields, Ukrainian companies have made little progress in commercializing these developments.

- The Ukrainian MIC is the most advanced and developed branch of Ukraine's economy.
- The Kolchuga–M, a new-generation, strategic, long-range, passive radar complex is one of Ukraine's success stories in the sensor field. Kolchuga–M provides early warning, locating communications and navigation signals and radar emitters from land, sea, or air platforms, including stealth aircraft, and detects takeoff and formation of aircraft at ranges beyond those of existing radar. The export of the Kolchuga to China, Ethiopia, Iran, Iraq, and, possibly, North Korea has created considerable international controversy.
- Improving the aircraft industry is a priority for Ukrainian economic development. Today Ukraine is among the top nine countries of the world able to boast of a full cycle of indigenous aviation hardware engineering and production.
- Ukraine possesses a complete space–rocket production complex, although it does not have, nor does it plan to develop, its own space launch facility. To support its aerospace industry, Ukraine hopes to provide commercial launch services using old Soviet intercontinental ballistic missiles (ICBMs) converted into launch rockets. Research priorities for the space sector include remote Earth sensing; telecommunication satellite systems; development of launch vehicles, ground infrastructure, and space vehicles; progressive space technologies such as the manufacture of space instruments; propulsion engineering; and materials science.
- Ukraine contributes 0.1 percent to the global high-tech market, while Germany contributes 16 percent; Japan, 30 percent; and the United States, 40 percent. In 2002, 4.7 percent of Ukraine's manufactured exports were high-tech goods, lagging behind most countries of the former Soviet Union and Eastern Europe, including Armenia, Bulgaria, Croatia, the Czech Republic, Estonia, Georgia, Hungary, Latvia, Lithuania, Poland, Romania, the Slovak Republic, and Slovenia. However, Ukraine outranks Russia and Moldova on this indicator. Ukraine exports most of its high-tech goods for consumption in former Soviet states or developing countries.
- The shortage of resources; the absence of experienced entrepreneurs, capable of establishing successful technology companies based on Ukrainian R&D achievements;

and the need to restructure the R&D community are the primary obstacles to the advancement of Ukraine's high-tech sector.

INTRODUCTION

Ukraine emerged from the Soviet Union with a wealth of research and development (R&D) resources and recognized capabilities in a number of science and technology (S&T) areas. However, Ukraine's S&T sector went into rapid decline in the face of economic and political crises that lasted into the 2000s. Ukraine's gross domestic product (GDP) in 2006 was higher than predicted, because of increased domestic consumption, manufacturing, and construction; rising world steel prices; and internal changes in Ukrainian economic policy, reforms, and institutional development. Nevertheless, in 2007 Ukraine's government programs, including those related to national R&D policy and the advancement of science, still lacked cohesion and clear direction.

During Soviet times, the Ukrainian Soviet Socialist Republic was second only to the Russian Soviet Socialist Republic in terms of economic strength. However, after the dissolution of the Soviet Union, drastic funding reductions for science affected the acquisition of state-of-the-art research equipment, the viability of long-term research projects, scientists' salaries, and even the prestige of the science and engineering community. The consequence was a gradual reduction in the number of state research establishments and the loss of many scientists to more profitable work within Ukraine or abroad, particularly to Israel, Russia, and the United States. After gaining its independence, Ukraine focused on the conversion of the military-industrial complex (MIC) to viable commercial activities in order to boost its economy. As a result of economic growth and the military conversion program, both the number of researchers and the amount of R&D funding have stabilized. Ukraine's current innovation policy is centered on the exploitation of scientific technological innovations for the purpose of economic growth.

The Ukrainian government's priorities for the country's innovative development through 2013 include power station modernization; new alternative and renewable energy sources; high-tech production in the machine-building, instrument-making, and metallurgy industries; development of nanotechnologies, microelectronics, information technology, telecommunications, chemical technologies, new materials, and biotechnologies; improvements in agriculture, food processing, transportation, and human and environmental health; and development of an innovation culture in Ukrainian society.

The Ukrainian MIC is the most advanced and developed branch of Ukraine's economy, including particularly the aircraft industry and aerospace industries. Ukraine is still a minor

contributor to the global high-tech market and exports most of its high-tech goods for consumption in former Soviet states or developing countries. The shortage of resources; the absence of experienced entrepreneurs, capable of establishing successful technology companies based on Ukrainian R&D achievements; and the need to restructure the R&D community are the primary obstacles to development of Ukraine's high-tech sector. Nonetheless, given the scientific resources that remained in Ukraine after the breakup of the Soviet Union, the country has the potential to become a major world player in certain sectors of the S&T economy.

ECONOMIC AND POLITICAL OVERVIEW

About the size of the state of Texas, Ukraine is one of the largest countries in Europe, second only to Russia in area and, with more than 46 million people (July 2007 estimate), ranking sixth in population, behind Russia, Germany, the United Kingdom (UK), France, and Italy.[1] Ukraine is strategically located between Europe and Asia. Its primary natural resources include arable land, graphite, iron ore, kaolin, manganese, magnesium, mercury, natural gas, nickel, oil, salt, sulfur, timber, and titanium; its main industries are chemicals, coal, electric power, ferrous and nonferrous metals, food processing (especially sugar), and machinery and transport equipment (including heavy engineering and shipbuilding). The Central Intelligence Agency (CIA) estimates that, in 2006, Ukraine's industry contributed 42.7 percent to the national GDP, with services contributing 39.8 percent and agriculture contributing 17.5 percent.[2]

After declaring independence in 1991 following the breakup of the Soviet Union, Ukraine fell into an economic crisis that persisted throughout the 1990s. According to World Bank data, among the former Soviet republics, Ukraine was the only country that did not grow between 1990 and 1999. GDP for the period dropped by more than 60 percent, while loose monetary policies led to hyperinflation starting in late 1993.[3] Whole industries—including electronics, for example—virtually disappeared, and domestic demand for many products, especially high-tech products, dropped dramatically.[4] Despite government programs to liberalize prices and establish a legal framework for privatization, many in Ukraine's government and

[1] United States, Central Intelligence Agency, "Ukraine," *The World Factbook* (Washington, DC, 2007), https://www.cia.gov/library/publications/the-world-factbook/geos/up.html (accessed August 1, 2007).
[2] CIA, "Ukraine."
[3] CIA, "Ukraine."
[4] Igor Yegorov and Artem Voitovych for Kyiv Information Services, "A Science Profile of Ukraine," British Council Ukraine, July 2004, 5, http://www.britishcouncil.org/ukraine-science-profile-eng.pdf.

legislature remained resistant to reform. Moreover, because Ukraine depended (and still depends) on imports, mostly from Russia, for three-fourths of its annual oil and natural gas requirements, Ukraine's economy was extremely vulnerable to external shocks. A case in point occurred in late 2005 and early 2006, when a dispute over natural gas pricing resulted in Russia's cutting off natural gas deliveries to Ukraine. The situation was resolved only after Ukraine concluded a deal with Russia that nearly doubled the price it paid for Russian gas.

Political turmoil continued to stunt the reform process well into the 2000s. The Orange Revolution at the end of 2004 resulted in nullification of a suspect presidential election; a new, internationally monitored election brought reformist Viktor Yushchenko into power. However, considerable internal squabbling within the Yushchenko camp led to the election of Yushchenko's rival Viktor Yanukovych as prime minister in August 2006, an event that finally brought some political stability to the country.[5]

Indeed, since the election of Yanukovych the political situation has calmed, and the economy has started to recover. Pressure from outside institutions—including the European Union (EU), the International Monetary Fund (IMF), the U.S. government, the World Bank, and the World Trade Organization (WTO)—has encouraged Ukraine to quicken the pace and scope of reforms. As part of its application to join the WTO, Ukraine passed more than 20 laws in 2006 alone, bringing its trading regime into conformity with WTO standards. Similarly, the officially stated desire to join the EU by 2011 has pushed Ukraine to normalize its legal, political, and economic regimes.

Both the CIA and the Ukrainian government report that Ukraine's GDP has grown in recent years. The Ukrainian government claims that, between 2000 and 2004, GDP grew by 50 percent, one of the highest growth rates in Europe. The CIA estimates that 2005 was relatively stagnant, with an increase in GDP of only 2.4 percent. Ukrainian officials predicted that the years 2006 and 2007 would show considerable growth. Indeed, in 2006 Ukraine's GDP increased by more than 7 percent, and during the first six months of 2007, by nearly 8 percent, outstripping the Ukrainian government's prediction of 6.5 percent for the year. Observers have attributed this growth to increased consumption (15.5 percent in the first six months of 2007), manufacturing (up 13.7 percent), and construction (up 11.8 percent). Rising world steel prices and internal changes in Ukrainian economic policy, reform, and institutional development are other factors

[5] CIA, "Ukraine."

contributing to growth. The Ukrainian government predicts an annual growth rate of 6 to 7 percent per year through 2010.[6] Nonetheless, in 2007 most government programs, including those related to national R&D policy and the development of science, still lacked cohesion and clear direction.[7]

Ukraine is a republic, with separate legislative, executive, and judicial branches. The country consists of 24 provinces (*oblasti*), one autonomous republic, and two municipalities with province status, Sevastopol and Kiev (Kyiv), the nation's capital. The president of Ukraine is the country's head of state and the highest official in the system of state authorities. Currently, the president is Viktor A. Yushchenko, elected in January 2005. The president, elected by direct universal popular vote for a five-year term, may serve a second term.

The Ukrainian national legislature, the Supreme Council (Verkhovna Rada), is a unicameral body with 450 seats. Supreme Council members, allocated on a proportional basis to those parties that attain 3 percent or more of the national electoral vote, serve five-year terms. The majority of the parliament selects the prime minister, who heads the Supreme Council. The current prime minister, Yuliya Tymoshenko, was elected in December 2007. Ukraine has a multiparty system, with so many parties that often they must form coalition blocs. Currently, the main parties or blocs in the Supreme Council are the Party of Regions (175 seats), Yuliya Tymoshenko Bloc (156 seats), Our Ukraine–People's Self Defense (72 seats), Communist Party of Ukraine (27 seats), and Lytvyn Bloc (20 seats). Ukraine's next elections are scheduled for 2012.[8]

UKRAINE'S S&T SECTOR

Under the Soviet Union

In Soviet times, the Ukrainian Soviet Socialist Republic (UkrSSR) was second only to the Russian Soviet Socialist Republic in economic strength, producing about four times the output of the next-highest-ranking Soviet republic. The UkrSSR also contributed to the Soviet Union's

[6] Ukraine, Ministry of Finance, "Ukraine in Brief" (powerpoint presentation, August 2007), http://minfin.gov.ua/control/en/publish/printable_article?art_id=64411.
[7] CIA, "Ukraine"; and Vadym Pischeyko et al, *Millennium Development Goals, Ukraine, 2001+5* (Kiev: Ministry of Economy of Ukraine, 2005), http://www.un.org.ua/files/MDG_Ukraine_2000_plus_5_ENG.pdf (accessed July 25, 2007).
[8] CIA, "Ukraine"; and Ukraine, government portal, http://www.kmu.gov.ua/control/en.

military might; about 40 percent of the total working population of Ukraine and about 60 percent of its industry contributed to the Soviet military apparatus.[9] Overall, the UkrSSR accounted for nearly 13 to 15 percent of the Soviet Union's scientific and engineering potential, about 50 percent of its R&D personnel, and about 20 percent of its experimental equipment.[10] The UkrSSR manufactured modern warships, missiles, and tanks, and the scientific world recognized the achievements of its researchers in biotechnologies, electric welding, mathematics, new materials, protective and reinforcing coatings, space studies, theoretical physics, transport aviation, and development of specialized software.[11] The world also knew of the UkrSSR's high concentration of experimental facilities operated by Soviet research organizations; the dominance within its R&D sector of industrial research (accounting for about 50 percent of total UkrSSR R&D personnel), and the high share of applied research. In terms of its R&D potential, the UkrSSR was better prepared for independent development than were the other Soviet republics, which had served as suppliers for Russia rather than as innovators.[12] A noted Russian expert in the area of science research, Andrei Terekhov, has noted, "only two of the most developed republics [of the Soviet Union], Russia and Ukraine, are capable of conducting research along all scientific front[s] and preparing specialists in all scientific areas."[13]

Changes in the 1990s

The country's S&T sector increasingly deteriorated throughout the 1990s.[14] After the dissolution of the Soviet Union, Ukraine had insufficient resources to preserve its science sector at the same level as under the Soviet regime. During the 1990s, the share of GDP involved in high-tech industries decreased, whereas the share in the mining, fuel, and metallurgy industries increased.[15] Drastic funding reductions for science affected the acquisition of state-of-the-art

[9] Yegorov and Voitovych, "A Science Profile," 3.
[10] Yegorov and Voitovych, "A Science Profile," 3.
[11] "The Science, Technology and Innovation System in the Ukraine," Internationale-kooperation.de, July 2005, http://www.internationale-kooperation.de/doc/ukraine_Final%5B1%5D_1553.pdf (accessed July 26, 2007); and Yegorov and Voitovych, "A Science Profile," 3.
[12] "The Science, Technology and Innovation System in the Ukraine," 3.
[13] Yegorov and Voitovych, "A Science Profile," 3.
[14] Oleg Bodruk, "Economic Principles Concerning the National Security of Ukraine and Conversion Problems for the Military-Industrial Complex," in *Defense Conversion, Economic Reform, and the Outlook for the Russian and Ukrainian Economies*, eds. Charles Wolf, Jr., Henry S. Rowen, and Jeanne Zlotnick, 205–15 (New York: RAND, 1994); and Yegorov and Voitovych, "A Science Profile."
[15] Yegorov and Voitovych, "A Science Profile," 5.

research equipment, long-term research projects, scientists' salaries, and even the prestige of the science and engineering community. The consequence was a gradual reduction in the number of state research establishments, as some collapsed, big research groups broke up into smaller ones, and Ukrainian R&D lost many scientists to more profitable work within Ukraine or abroad (primarily to Russia, Israel, and the United States).[16] This reduction occurred despite the introduction of various national programs in the power engineering and coal mining sectors, which gave scientific, engineering, and innovative factors top priority.[17] What remained, according to Valentin Badrak, director of the Center for Army, Conversion, and Disarmament Studies in Kiev, was approximately 500 scientific-technical and design organizations, employing about 60,000 experts engaged mostly in R&D for the military and dual-use production in the civilian sector.[18]

Because the Ukrainian economy was so heavily involved in the defense sector during the Soviet period, one of Ukraine's most important economic activities after gaining its independence was the conversion of the MIC to viable commercial activities, with technology playing a key role. In 1994 Oleg Bodruk, who was at that time head of the Department of International Security at the Institute of World Economy and International Relations of Ukraine and had served as consultant to the minister of defense during the Kravchuk administration, wrote that, "A good conversion model should guarantee the development of production based on scientific and technological progress." Among the criteria Bodruk lists for accomplishing conversion are:

> Maintaining and developing new technologies; preserving accumulated technological knowledge within the defense complex; and exchanging advanced technologies among enterprises of the defense complex and adjacent branches in order to most effectively use scientific achievements and technological progress.[19]

The presidential decree entitled *On Measures for Stabilizing Scientific Research Work and R&D Organizations and Industries of Defense and Engineering Complexes of Ukraine* (1992) mandated that the government provide assistance, including financial assistance, to enterprises

[16] Yegorov and Voitovych, "A Science Profile," 4.
[17] Valentin Badrak, "Ukraine Gambles on Technologies," *Defense Express* (Kiev), January 1, 2003 (accessed June 22, 2007, via Eastview).
[18] Badrak, "Ukraine Gambles on Technologies."
[19] Bodruk, "Economic Principles Concerning National Security."

and scientific organizations subject to conversion for "the preservation of the scientific, technical, and industrial potential of Ukraine's major enterprises."[20]

In the 1990s, because the primary source of funding for Ukrainian R&D was from overseas, Ukrainian scientific activity became oriented toward the interests of foreign customers, rather than the needs of the Ukrainian economy. As a result, according to a 2003 report on the state of science in Ukraine, the country "is gradually acquiring a system that is basically oriented to the import of scientific and engineering outcomes instead of making its own science and technology products."[21]

Ukrainian S&T Since 2000

According to the Ukraine Ministry of Economy, as the result of the Ukrainian economy's growth and the country's focus on conversion of its MIC to civilian production, both the number of researchers and the amount of R&D funding have stabilized. The World Bank's comparative analysis of the main production factors in the Ukrainian economy against the six most developed economies in the world (the United States, Japan, Germany, France, the UK, and Canada) reveals that Ukraine's rating is relatively high. Ukraine is third in agricultural land resources, fourth in labor resources, and third in scientific potential.[22]

According to Gerson Sher, a U.S. expert on scientific cooperation with the countries of the former Soviet Union and Eastern Europe, today Ukraine has strong research potential in aviation, biochemistry, crystallography, mathematical and computer modeling, and metallurgy, among other fields.[23] However, specialists say there is still a crisis in Ukrainian science—the scientific system needs institutional, legal, and regulatory reform, and links between economic policy and S&T policy remain rather weak.[24] These issues impede the country's ability to develop its huge research potential, development necessary to fuel Ukraine's economic growth.

[20] Victor I. Antonov, "Conversion of Military Industries in Ukraine," in *Defense Conversion, Economic Reform, and the Outlook for the Russian and Ukrainian Economies*, eds. Charles Wolf, Jr., Henry S. Rowen, and Jeanne Zlotnick, 149–62 (New York: RAND, 1994).
[21] Yegorov and Voitovych, "A Science Profile," 5.
[22] Pischeyko et al, *Millinium Development Goals*.
[23] Gerson S. Sher, "The Role of International Collaboration in Enhancing Ukrainian Research Potential," U.S. Civilian Research and Development Foundation, 2007, http://www.crdf.org/focus/focus_show.htm?doc_id=290096 (accessed July 19, 2007).
[24] Yegorov and Voitovych, "A Science Profile," 6.

Although some recovery has occurred recently, Ukraine's scientific research system is still a "shadow of its former self."[25]

UKRAINE'S S&T POLICY

Under Ukraine's current innovation policy, the government plans to exploit scientific technological innovations for the purpose of economic growth. However, because of the limited resources available to the S&T sphere—inadequate government and private-sector financing, labor, modern facilities, and equipment—to date Ukraine has not implemented its innovation policy.[26]

Institutions Involved in Setting S&T Policy

The president's office, the Cabinet of Ministers, the Supreme Council, and the Ministry of Education and Science are the main organizations in Ukraine involved in setting and implementing S&T policy.

President and Cabinet of Ministers

The president of Ukraine has the following powers in administering S&T policy:

- Determining the system of executive power authorities administering S&T
- Overseeing the establishment and operation of public S&T administration
- Establishing an advisory council responsible for S&T policy
- Determining priorities in S&T
- Developing strategies for S&T and innovation
- Considering effective use of state funds to develop S&T and innovation, particularly directed toward structural improvement of S&T administration, training, and certification

[25] Sher, "Role of International Collaboration"; and Yegorov and Voitovych, "A Science Profile," 6.
[26] *Towards a Knowledge-Based Economy, Ukraine, Country Readiness Assessment Report—Ukraine* (Geneva and New York: United Nations Economic Commission for Europe, 2003), http://www.unece.org/ie/enterp/documents/ukraine.pdf.

The S&T Policy Council is the advisory authority for the president of Ukraine. However, in 2003 analysts reported that the council's performance was extremely poor. As of this writing, available resources do not reveal whether the council still exists.[27]

Executive power for determining S&T policy lies with the Cabinet of Ministers of Ukraine. The cabinet has the following powers:

- Proposing to the Supreme Council priorities in national science and engineering development and logistical support
- Implementing national S&T programs
- Approving interdepartmental S&T programs according to the priorities of S&T development adopted by the Supreme Council of Ukraine[28]

Supreme Council

The Supreme Council of Ukraine (Verkhovna Rada) has the authority to legislate S&T policy. The Supreme Council has the following responsibilities:

- Implementing public administration in S&T
- Formulating and approving the regulatory framework for the S&T sector
- Defining basic principles and directions of public policy regarding S&T
- Approving priority areas and national programs for S&T development[29]

Ministry of Education and Science

The Ukraine Ministry of Education and Science (MES) is the leading authority directly implementing public policy regarding education, intellectual property, S&T, and innovation. The Cabinet of Ministers of Ukraine governs and coordinates the activities of MES. In addition to implementing public policy, MES determines the priorities for development in the fields of education, S&T, intellectual property, and innovation, and ensures the systematic integration of national education and scientific development, so as to protect national interests.[30]

[27] Yegorov and Voitovych, "A Science Profile," 22–23.
[28] Yegorov and Voitovych, "A Science Profile," 25–26.
[29] Yegorov and Voitovych, "A Science Profile," 22.
[30] Yegorov and Voitovych, "A Science Profile," 23.

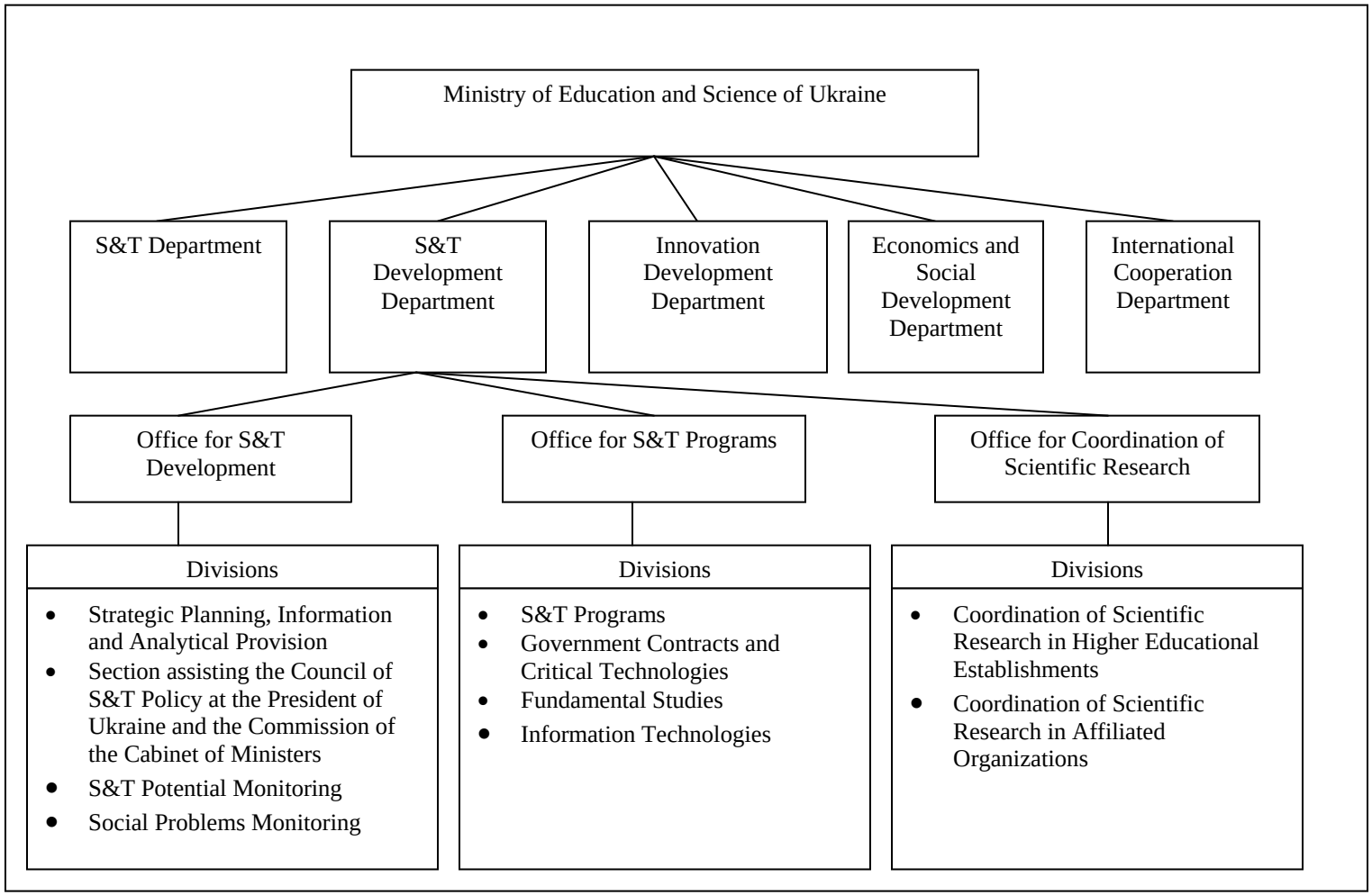
MES consists of five S&T departments: S&T, S&T Development, International Cooperation, Economics and Social Development, and Innovation Development.[31] Whereas the S&T Department appears to be primarily administrative, the S&T Development Department seems to be the central body guiding scientific development. The S&T Development Department includes the Office for S&T Development; the Office for S&T Programs; and the Office for Coordination of Scientific Research. The International Cooperation Department engages in various activities associated with international cooperation of Ukrainian educational establishments, research facilities, government departments, and nongovernmental organizations (NGOs) in the areas of education and science.[32] The Economics and Social Development Department is involved with government programs for education and science, determines levels of state funding, and provides for the social framework for students and science workers. The Innovation Development Department is the primary office responsible for strategic planning for S&T development, innovation activities, and technology transfer. See figure 1 for a schematic of the administrative organization of MES.

In addition, each ministry has a department responsible for administration of scientific and innovation activities falling within its jurisdiction. These departments have the following responsibilities:

- Determining directions for future S&T development
- Supervising and controlling activity of subordinate research organizations
- Participating in forming national S&T priorities and state S&T programs
- Concluding government contracts
- Establishing programs for S&T development within their respective industries
- Organizing program implementation
- Arranging to bring to market competitive, innovative technologies, equipment, and materials
- Making proposals to improve the economic conditions for fostering S&T development in their respective industries[33]

[31] Yegorov and Voitovych, "A Science Profile," 23.
[32] Yegorov and Voitovych, "A Science Profile," 23.
[33] Yegorov and Voitovych, "A Science Profile," 23.

Figure 1. Ukraine, Ministry of Education and Science, S&T Departments



Source: Based on information from Igor Yegorov and Artem Voitovych, for Kyiv Information Services, "A Science Profile of Ukraine," July 2004, http://www.britishcouncil.org/ukraine-science-profile-eng.pdf; and Ukraine, Ministry of Education and Science, "Structure of the Ministry of Education and Science" [in Ukrainian], http://www.mon.gov.ua/ministry/structure.

Legislation Governing the S&T Sector

Ukraine has an entire system of legislative acts and regulations providing the legal framework for its S&T activities. This framework provides

- basic forms and techniques to regulate S&T development;
- S&T outcomes to modernize production; to satisfy the needs of the public; and to meet primary objectives, directions, and principles of public S&T policy;
- powers of public authorities; and
- economic and legal guarantees of S&T potential development in Ukraine.[34]

Ukraine continues to update and amend regularly the following three major laws regarding S&T:

- *Law of Ukraine, On the Fundamentals of Public Policy in the Sphere of Science and Technology Activities,* No. 284–XIV, effective December 13, 1991, defines the legal, organizational, and financial principles behind the functioning and development of S&T. This law creates conditions for Ukraine's S&T activities to ensure that these activities meet societal needs and reflect the country's level of technological development. The law empowers the Cabinet of Ministers to establish S&T programs at the national, state, international, industrial, interdisciplinary, and regional levels and addresses the mechanisms for their funding. The purpose of the law is to concentrate the country's efforts on "priority directions of science and technology progress and solving acute socio-economic, scientific, engineering, environmental problems of development of Ukrainian industry on the basis of innovative technologies and materials with effective assistance rendered by the state to this process." However, critics argue that the law does not "establish certain measures in science development, producing and implementing innovations, mastering high-tech production and making competitive products."[35]
- *Law of Ukraine, On Priority Branches of Science and Technology Development* No. 2623–III, effective August 2, 2001, defines the legal, financial, and organizational principles for establishing and implementing priority branches for the S&T development of Ukraine. These priority areas are an integral part of the country's economic and social development plans. The Cabinet of Ministers formulates the priority areas for a five-year

[34] Yegorov and Voitovych, "A Science Profile," 25.
[35] "Ukrainian Legislative Database," Yaroslav the Wise Institute of Legal Information, http://www.welcometo.kiev.ua/pls/ili/ili.home (accessed August 10, 2007); and Yegorov and Voitovych, "A Science Profile," 25.

period (2001–2006 is the last such period for which the list of priorities is available), based on the "technology development forecast" for the country. The cabinet submits the list of priorities to the Supreme Council of Ukraine, by March 1 of the last year of the previous five-year period (in this case, 2006). These plans are subject to the availability of funds for S&T in the state budget of Ukraine. The law defines the following priority branches of S&T development for the period through 2006:

- Basic research in the most important aspects of natural, public, and humanitarian sciences
- Problems in the area of demographic policy, development of human potential, and forming of a civil society
- Environmental conservation and sustainable development
- Modern biotechnologies, specifically diagnostics and methods for treatment of widespread diseases
- Modern computer devices and technologies for the "informatization" of society
- Modern technologies and resource-saving technologies in energy, industry, and agriculture, including modern substances and materials[36]

- *Law of Ukraine, On Priority Directions of Innovation Activity in Ukraine* No. 433–IV**,** effective February 13, 2003, creates a legal basis for concentrating the state's resources on medium-term, strategic priorities. The highest priority is the scientific and technological modernization of production and services in the country, emphasizing societal needs, high technology, competitiveness, responsibility for the environment, quality, and the development of export potential. Currently, the law sets forth the following strategic medium-term priorities for innovation for the period from 2003 to 2013:
  - Modernization of power stations
  - Development of new alternative and renewable energy sources
  - High-tech development of the machine-building, instrument-making, and metallurgy industries
  - Development of nanotechnologies, microelectronics, information technology, and telecommunications
  - Improvement in chemical technologies, new materials, and biotechnologies

[36] "Law of Ukraine of 11.07.2001 No. 2623–III On Priority Branches of Science and Technology Development," Verkhovna Rada Ukraina, http://zakon.rada.gov.ua/cgi-bin/laws/anot.cgi?nreg=2623-14 (accessed August 13, 2007).

- High-tech development of agriculture and the food-processing industry
- Building and reconstruction of transport systems
- Improvement of human and environmental health
- Development of an innovation culture in Ukrainian society[37]

Critics have stated that the vague formulation of the law, and of the government's policy on innovation, has resulted in too many businesses with access to the monetary privileges available under this law.[38]

Other laws that affect the development of S&T in Ukraine include the following:

- On Scientific and Scientific Technical Expertise
- On Scientific and Technical Information
- On the Investment and Innovative Activity of Technological Parks
- On the Activities of the National Academy of Sciences of Ukraine
- Intellectual property rights law
- Patenting law

Also relevant are the following general laws:

- On Ownership
- On Enterprises
- On Taxation of Incomes of Enterprises and Organizations
- On Foreign Investments

It is evident that Ukraine has well-developed legislation in the area of S&T. However, not all of these laws are direct-action laws. This means that the laws require numerous regulatory bylaws to supplement them. These laws have proven difficult to implement. Moreover, many organizations have taken advantage of the privileges intended for scientific and innovative organizations, while relatively few of them are prosecuted for their infractions. In addition, the government has adopted these laws in a rather disorganized manner, which some experts believe reflects the lobbying by specific groups, companies, and regions.[39]

In 2003 the Ukraine government announced its intention to take a number of steps to invigorate S&T policy. Measures were to include the following:

[37] "Law of Ukraine On Priority Branches of Science and Technology Development."
[38] Badrak, "Ukraine Gambles on Technologies"; and Yegorov and Voitovych, "A Science Profile," 25.
[39] Yegorov and Voitovych, "A Science Profile," 31.

- Developing organizational and economic mechanisms of R&D planning, funding, and implementation
- Developing and implementing innovations
- Developing the legal framework regulating science and innovation activities and, especially, defining state priorities in S&T and intellectual property protection
- Restructuring the national network of research organizations and introducing new forms of ownership of research establishments
- Making an inventory of state-funded research organizations and determining Ukraine's state scientific assets
- Implementing pay increases for scientists and engineering personnel in R&D organizations
- Expanding international cooperative S&T ventures, participating in relevant international agreements, and becoming involved in a single European research sector[40]

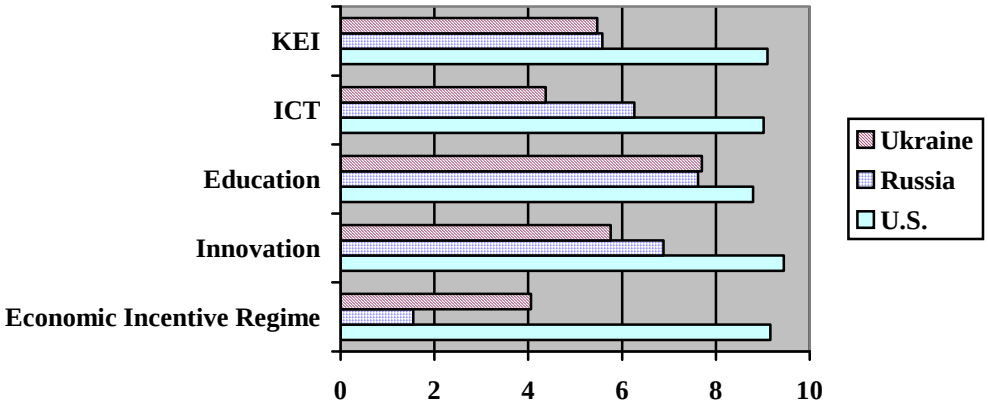
UKRAINE'S R&D RESOURCES

Since the competitiveness of any economy depends on its ability to use the results of R&D in production, knowledge is a key factor in measuring economic growth.[41] According to the World Bank's Knowledge Economy Index (KEI) of 2007, Ukraine ranks behind most of Western Europe, Central Europe, Russia, and many Latin American countries as measured by the KEI. In determining a country's rank, the KEI factors in a country's economic incentive regime, based on tariff and nontariff barriers, regulatory quality, and rule of law. The KEI also measures a country's level of innovation based on the number of researchers in R&D, patents granted by the U.S. Patent and Trademark Office, and S&T articles published in scholarly journals; education, based on a combination of adult literacy rate and secondary and tertiary school enrollment; and information and communications technology (ICT) usage based on the level of computer, telephone, and Internet penetration. On the KEI scale, Ukraine ranks relatively high in its level of education (7.4 points out of 10), but drops to near and below 5 out of 10 in its level of

[40] Yegorov and Voitovych, "A Science Profile," 71–72.
[41] Olena Etokova, "Development of Knowledge Economy for Improvement of International Competitiveness of Ukraine," Bulgaria, Ministry of Finance, 2005, http://www.aeaf.minfin.bg/documents/Olena_Etokova_PAPER_CMTEA2005.pdf.

innovation, economic incentive regime, and ICT penetration.[42] See figure 2 for a comparison of Ukraine, Russia, and the United States on the KEI scale.

Figure 2. Comparison of the Knowledge Economy Index (KEI) and Its Component Measures for Ukraine, Russia, and the United States, 2008



Source: World Bank, *Knowledge Economy Index and Knowledge Index* (KAM 2007), 2007, http://info.worldbank.org/ etools/kam2/KAM_page5.asp#c72.

Lack of resources is a major factor in the slow recovery and development of Ukraine's science sector. State funding of R&D has dropped steadily since the 1990s, and the country has suffered a brain drain, as researchers previously employed in the Soviet Union's weapons of mass destruction (WMD) program look for other meaningful, paid work, mostly in Russia. The state has neither maintained, nor updated, the sector's aging facilities and equipment. The following sections discuss the state of S&T resources, including funding, workforce, and equipment and facilities.

R&D Funding

According to law, S&T funding is a secured expenditure item in the state budget of Ukraine. Ukraine's S&T funding is directed toward fundamental scientific research; research in critical sectors, including national security and defense; development of the S&T infrastructure;

[42] World Bank, *Knowledge Economy Index and Knowledge Index* (KAM 2007), 2007, http://info.worldbank.org/ etools/kam2/KAM_page5.asp#c72; and Igor Yegorov, "The Transformation of R&D Potential in Ukraine Europe," *Europe-Asia Studies*, June 1995, http://findarticles.com/p/articles/mi_m3955/is_n4_v47/ai_17153855 (accessed July 11, 2007).

preservation of national scientific assets; and training of research personnel. The Cabinet of Ministers determines which scientific institutes and higher education establishments are eligible for state S&T funding.[43]

National R&D spending in Ukraine decreased by 40 percent throughout the 1990s, although expenditures began creeping up beginning in 1998. Moreover, funding of R&D in the 1990s declined at a faster pace than GDP, largely because R&D expenditures on leases and utilities were soaring. With wages making up more than 50 percent of costs in some sectors, personnel costs became an increasing burden on R&D establishments, as well.[44] However, the government was not always able to meet its targeted contributions. In 1998, for example, the government was able to provide only 50 percent of planned funds for R&D and innovation. In 1999 this number increased to 77 percent.[45] Even in years of rapid economic growth (2000–2002), the level of R&D allocations from the state budget was below 100 percent.[46]

The following types of institutes provide Ukrainian researchers with the best opportunities for decent work conditions and wages:

- Industry institutes with firm links to large businesses in Ukraine and Russia. For example, the Russian gas giant Gazprom provides significant funding for several design bureaus in Ukraine's gas industry.
- Institutes that have established mutually beneficial relationships with scientific organizations in developed countries. Employees of these institutes regularly obtain grants for equipment, conduct research, participate in conferences, travel abroad, etc. The biological and mathematical institutes of the National Academy of Sciences of Ukraine (NASU) fall into this category.
- Institutes that have contracted to conduct various studies and to take part in political campaigns. Average wages in these institutes can be approximately twice those of other institutes.[47]

[43] Yegorov and Voitovych, "A Science Profile," 38.
[44] Yegorov and Voitovych, "A Science Profile," 36.
[45] Yegorov and Voitovych, "A Science Profile," 38.
[46] Yegorov and Voitovych, "A Science Profile," 38.
[47] Yegorov and Voitovych, "A Science Profile," 13.

R&D Funding as a Percentage of GDP/GNP[48]

Ukraine has a small budget allocation for science in general, and related R&D in particular, compared to most developed countries.[49] In the mid-1990s, R&D expenditures in most West European countries exceeded 2 percent of gross national product (GNP); Sweden dedicated 3.4 percent of GNP to scientific R&D; Finland, 2.5 percent; and the Netherlands, 2.1 percent. In the early 2000s, in comparison to other emerging markets, R&D funding in South Africa and Russia was 0.7 percent of GNP, and in India, 0.8 percent.[50] Nonetheless, despite the government's pledge to increase government funding for science to a minimum of 1.7 percent of GNP by 2000, Ukraine's expenditures in the early 2000s did not surpass 0.3 percent of GNP.[51] In 2000 the EU's heads of state met and formulated the Lisbon Strategy, a series of ambitious proposals aimed at making the EU, which Ukraine aspires to join, "the most dynamic and competitive knowledge-based economy in the world by 2010."[52] According to the Lisbon Strategy, Ukraine should aim for its R&D spending, as a percentage of GDP, to reach 3 percent by 2010, with businesses providing two-thirds of all R&D funds.[53] See figure 3 for a comparison of the change in R&D expenditures in Ukraine from 1990 through 2004.

[48] GDP and GNP are very similar measures. Gross domestic product (GDP) measures the value of all final goods and services produced in a country during the year. GDP includes consumption, investment, government purchases, and exports-less-imports from other countries. Gross national product (GNP) measures the value of all final goods and services produced by economic inputs supplied by a country's residents. GNP equals GDP plus income received from the rest of the world minus income paid to the rest of the world, http://www.economicadventure.org/teachers/glossary_econ.cfm.

[49] Zinayida Klestova, *The Experience of Development of Technology Transfer Groups in Ukraine* (Kiev: Ukrainian Branch of Euroscience Working Group of Technology Transfer, 2002), http://www.kiev.technology-transfer.net/year2002.htm (accessed August 16, 2007).

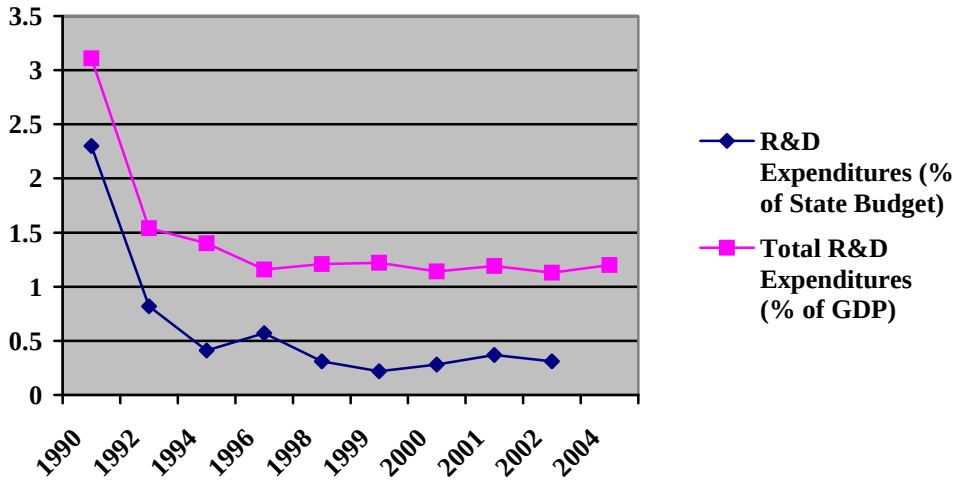
[50] Badrak, "Ukraine Gambles on Technologies."

[51] Badrak, "Ukraine Gambles on Technologies."

[52] Olya Verkhohlyad, "Evaluation of Capacities Ukraine Has Toward Meeting the Requirements of the EU-Ukraine Action Plan (2004) in the Areas of Research and Education" (report, Texas A&M University, College Station, TX, April 2005), http://international.tamu.edu/eunotes/Spring_2005/olya-paper.doc.

[53] Verkhohlyad, "Evaluation of Capacities Ukraine Has Toward Meeting the Requirements of the EU-Ukraine Action Plan (2004) in the Areas of Research and Education."

Figure 3. Ukraine: R&D Expenditures 1990–2004



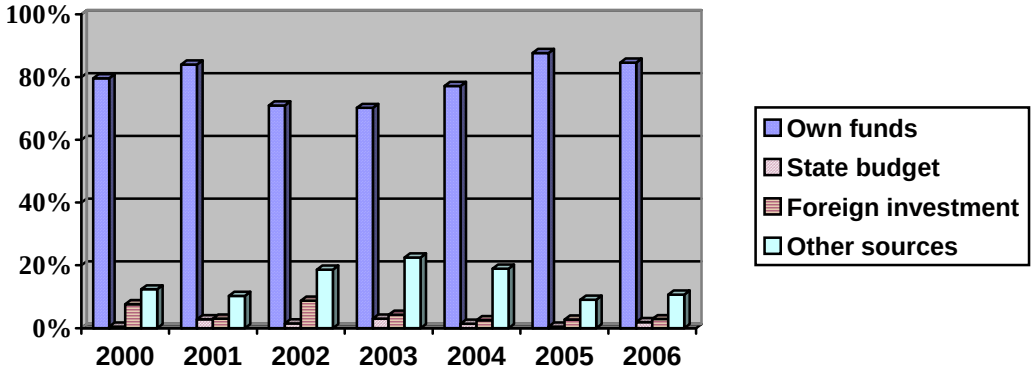
Sources: Based on information from Igor Yegorov, "Post-Soviet Science: Difficult Way of Reforms," University of Sussex, SPRU - Science and Technology Policy Research, July 14, 2006, http://www.sussex.ac.uk/Units/spru/events/ocs/viewabstract.php?id=75 (accessed August 22, 2007); and "The Science, Technology and Innovation System in Ukraine," Internationale-kooperation.de, July 2005, http://www. internationale-kooperation.de/doc/ukraine_Final%5B1%5D_1553.pdf (accessed July 26, 2007).

Financing Sources for R&D

State funding of publicly owned S&T organizations declined by nearly 12 percent from 1996 to 2000, while business-sector and foreign investments rose by 8.1 percent and 3.4 percent, respectively, during the same period.[54] Today the private sector funds most R&D in Ukraine.[55] See figure 4 for a breakdown of the sources of financing of technological innovations in Ukraine from 2000 through 2006.

[54] Yegorov and Voitovych, "A Science Profile," 38.
[55] Yegorov and Voitovych, "A Science Profile," 38.

Figure 4. Ukraine: Sources of Financing for Technological Innovations, 2000–6 (in percentages)



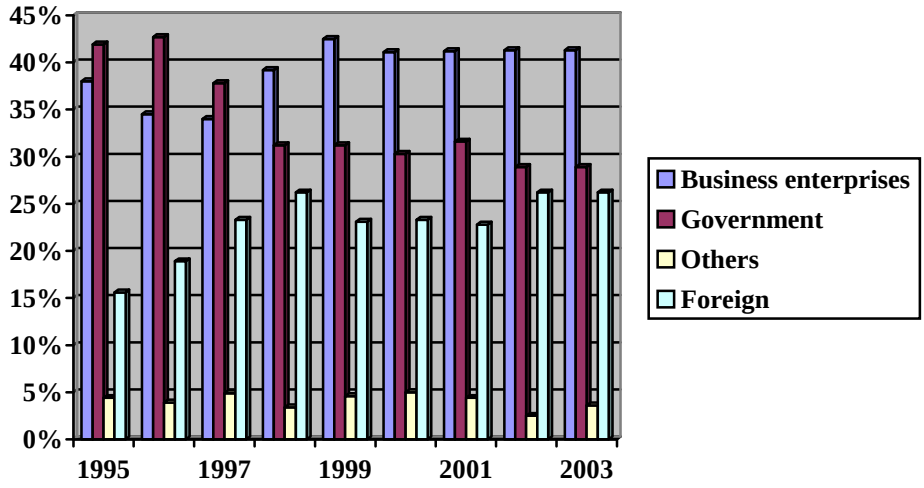
Source: Based on information from Ukraine, State Statistics Committee of Ukraine, "Statistical Information, Research and Development Activity, 1995–2006," 2007, http://ukrstat.gov.ua/control/en/localfiles/display/operativ/operativ2005/ni/ind_rik/ind_e/2002_e.htmL (accessed August 22, 2007).

Public versus Private Financing

As mentioned above, Ukraine has experienced a considerable decline in its public research sector, including R&D in the MIC, while, at the same time, the private research sector (including some industries and science-intensive small and medium enterprises) is well established and expanding at a rapid rate. The R&D sector of the MIC also has declined. Because of comparatively low demand for S&T products from domestic customers, the privatization of research establishments in Ukraine is proceeding slowly. Even for those organizations not formally state-owned, the government usually owns more than 50 percent. Experts are concerned about the steadily declining share of government expenditures and the rapidly growing share of foreign funds supporting Ukraine's R&D. According to analysts from NASU's Ukrainian Center for S&T Potential and Science History Studies, foreign funding for Ukrainian R&D increased from 15.6 percent of total R&D investment in 1995 to 26.2 percent in 2003, showing a slight decline to 23.3 percent in 2004.[56] See figure 5 for R&D expenditures by source of funds for 1995 through 2003.

[56] Lidiya Kavunenko and Tatyana Goncharova, "International Cooperation of Ukraine: Barriers on the Way to Equal Integration" (paper presented at International Workshop on Webometrics, Informetrics and Scientometrics and Seventh COLLNET Meeting, Nancy, France, May 2006), http://eprints.rclis.org/archive/00006350/01/ukraine.pdf (accessed September 30, 2008).

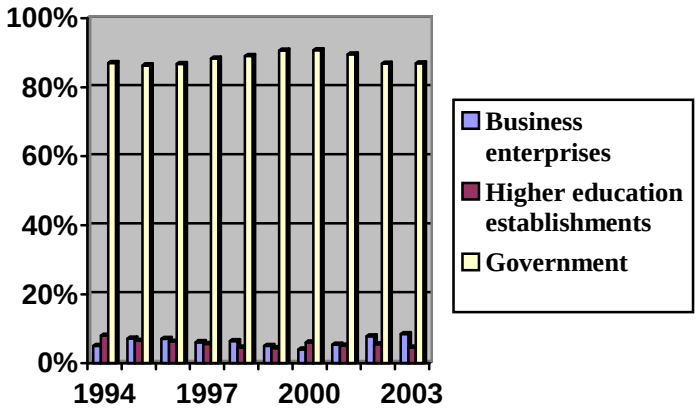
Figure 5. R&D Expenditures by Source of Funds, 1995–2003 (in percentages)



Source: Based on information from "The Science, Technology and Innovation System in Ukraine," Internationale-kooperation.de, July 2005, http://www.internationale-kooperation.de/doc/ukraine_Final%5B1%5D_1553.pdf (accessed July 26, 2007).

The public sector continues to lead the way in using R&D funds. See figure 6 for R&D expenditures by sector of performance for 1994–2003.

Figure 6. R&D Expenditures by Sector of Performance, 1994–2003 (in percentages)

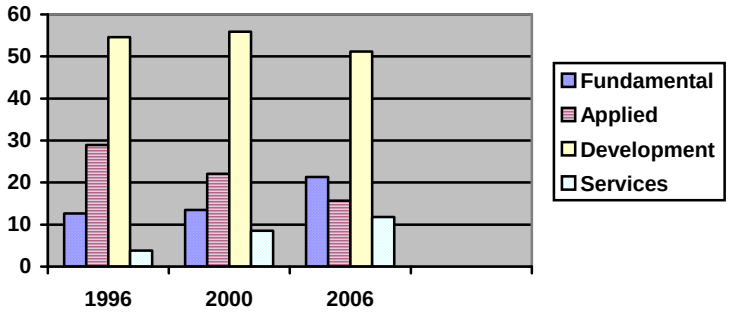


Source: Based on information from "The Science, Technology and Innovation System in Ukraine," Internationale-kooperation.de, July 2005, http://www.internationale-kooperation. de/doc/ukraine_Final%5B1%5D_1553.pdf (accessed July 26, 2007).

Funding by Types of R&D

The Ukrainian statistical service provides data on the type of R&D work performed—fundamental research, applied research, experimental development, or research services. According to this data, Ukraine's R&D is strong in experimental development, but a shift has occurred since 1996, with applied research in decline, while fundamental research and research services are on the rise.[57] According to Ukraine's current strategy, the central government will "assume complete responsibility for development of fundamental studies and ensure national S&T security," while manufacturers, private investors, banks, nonprofit organizations, and foreign investors will develop applied research and implement innovations. See figure 7 for a comparison of the type of research work performed in Ukraine between 1996 and 2006.

Figure 7. Ukraine: Type of R&D Work Performed, 1996, 2000, 2006 (in percentages)



Source: Based on information from Ukraine, State Statistics Committee of Ukraine, "Statistical Information, Research and Development Activity, 1995–2006," 2007, http://ukrstat.gov.ua/control/en/localfiles/display/operativ/operativ2005/ni/ind_rik/ind_e/2002_e.htmL (accessed August 22, 2007).

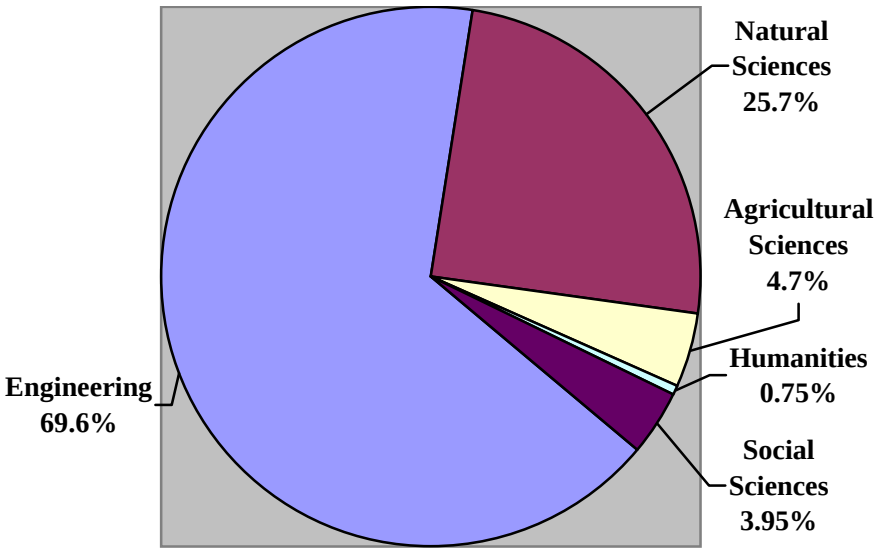
R&D Spending by S&T Sector

Ukraine distributes funds from the state budget among the engineering sciences, natural sciences, agricultural sciences, humanities, and social sciences.[58] Engineering received the lion's share of funding—almost 70 percent in 2001 (a decline from 2000); natural sciences came in second with more than 25 percent of overall S&T funding (an increase over 2000); followed by

[57] Ukraine, State Statistics Committee of Ukraine, "Statistical Information, Research and Development Activity, 1995–2006," 2007, http://ukrstat.gov.ua/control/en/localfiles/display/operativ/operativ2005/ni/ind_rik/ind_e/2002_e.htmL (accessed August 22, 2007).
[58] Yegorov and Voitovych, "A Science Profile," 41.

agricultural sciences (at 4.7 percent, a notable increase from 2000); humanities at 0.75 percent (a slight increase from 2000); and social sciences at 3.95 percent (an increase from 2000).[59] Ferrous metallurgy, the gas and oil extracting industry, and machinebuilding receive the most funding, mostly because of the support of the Ministry of Industrial Policy.[60] See figure 8 for a graphical representation of Ukraine S&T funding by sector for 2001.

Figure 8. Ukraine S&T Funding by Sector, 2001



Source: Based on information from Igor Yegorov and Artem Voitovych for Kyiv Information Services, "A Science Profile of Ukraine," British Council Ukraine, July 2004, http://www.britishcouncil.org/ukraine-science-profile-eng.pdf.

The Banking Sector

One important precondition for technological, economic, and business development is creating attractive conditions for commercial banks to participate in innovative projects. In 2002 Ukrainian commercial banks participated for the first time in innovative projects, and in 2003 they planned to allocate approximately US$85 million for realization of the long-term projects of state businesses. The first banks involved in this sphere were Prominvestbank (a joint-stock commercial industrial and investment bank); Aval (an open joint-stock company, part of Raiffeisen International Bank-Holding AG of Austria); and Vabank (one of Ukraine's top 20

[59] Yegorov and Voitovych, "A Science Profile," 42.
[60] Yegorov and Voitovych, "A Science Profile," 38–39.

banks and part of the VAB Group universal financial consortium). The banking sector made early credits to Kharkov's FED Machinebuilding Factory, which specializes in the manufacture of integrated hydro drives, fuel-regulating devices, electric-driven pump stations, and hydroblocks for the aerospace and mechanical engineering industries, and extended other credits to Motor-Sich Share-Holding Company, for serial production of a new generation of aircraft engines, and to Kharkov's State Aircraft Manufacturing Factory, for the manufacture and production of the An–140, An–74TK–300, and An–74TK–300UT aircraft.[61]

Government Incentive Programs Promoting R&D

Tax Incentives

To stimulate R&D, the Ukrainian national government provides tax breaks to some organizations. For example, enterprises and organizations earning income through S&T programs financed from the state budget are exempt from taxation of that income. [62] According to the *Law of Ukraine On Taxation of Incomes of Enterprises and Organizations,* the state taxes income of research enterprises at 50 percent of the tax rate of other Ukrainian enterprises. The State Fund of Fundamental Studies, innovation foundations, and other registered state innovation organizations are exempt from taxes; enterprises, establishments, and organizations making free-will payments into these funds pay taxes reduced by a pro-rated amount.[63]

The State Innovation Fund/State Innovation Company of Ukraine (SICU)

On February 12, 1992, a Cabinet of Ministers resolution established the State Innovation Fund, designed to further the progress of Ukrainian science by providing

> financial, material and technical support for regional and other science and technology programs, [applying] scientific developments in the industry, [creating] 'know-how,' [expanding] the application of advanced technologies, [and developing] competitive products.[64]

Budgetary appropriations allocated for scientific research; sales tax of 1 percent on enterprises, associations, and organizations; and independent contributions were to provide the funds.

[61] Badrak, "Ukraine Gambles on Technologies."
[62] Yegorov and Voitovych, "A Science Profile," 28.
[63] Yegorov and Voitovych, "A Science Profile," 28.
[64] Yegorov and Voitovych, "A Science Profile," 27.

However, the government misused the funds (for example, for paying state salaries that were in arrears), and nothing was accomplished. In 2000 the State Innovation Company of Ukraine (SICU) replaced the State Innovation Fund.[65]

The main objectives of SICU, established as a non-bank financial credit organization, were to realize Ukraine's innovation policy and to attract national and foreign investors for the development of the national economy, including the application of S&T achievements in industry and the development of new products.

Currently SICU has a considerable material and technical basis, in addition to a well-developed infrastructure. SICU, a shareholder of the joint stock company Ukrainian Bank of Reconstruction and Development, has 16 regional departments in addition to its headquarters in Kiev. As of January 2006, evidence indicated that SICU was still operational. At that time, SICU reported that its priority credit activity was financing projects at technoparks.[66]

Foreign Direct Investment in R&D

Ukraine trails other countries in foreign direct investment (FDI), in both investment volume and structure. For example, as of January 1, 2001, Ukraine received US$3.9 billion in FDI. In comparison, China received US$40 billion in FDI in 1999. Between October 2001 and June 2002, 32 percent of investment in Ukraine went to the financial, wholesale, and retail sectors, whereas only 3.1 percent went to mechanical engineering. According to Valentin Badrak, director of the Center for Army, Conversion and Disarmament Studies in Kiev, "this demonstrates that there were few stimuli in Ukraine to attract investments to technologies and hi-tech manufacturing, and secondly, that foreign countries underestimate Ukraine's existing potential, which is especially high in the field of both the development and manufacture of arms and dual-purpose production."[67] The United States is the source of the largest volume of FDI in the Ukrainian economy (22 percent of the total), followed by Cyprus (20 percent) and the United Kingdom (17 percent). Cyprus's significant share of investment indicates that the capital taken out of Ukraine by Ukrainian citizens during the period of economic and social instability of the early 1990s is returning. In 2005 foreign investment in the Ukrainian economy made up 2.4

[65] Yegorov and Voitovych, "A Science Profile," 27.
[66] "Projects of Technological Parks—Priority Task of SICU's Credit Activity," State Finance Institution for Innovations, February 20, 2006, http://www.udik.com.ua/eng/news/?id=42.
[67] Badrak, "Ukraine Gambles on Technologies."

percent of GDP (US$177 per capita), while at the end of 2002, per capita FDI in the Czech Republic was US$3,000; in Estonia, US$2,600; in Hungary, US$2,400; in Slovenia, US$2,000; and in Poland, US$1,200.[68] The volume of FDI in Ukraine at the beginning of 2005 was US$8.4 billion. Poland surpassed this amount in 1995.

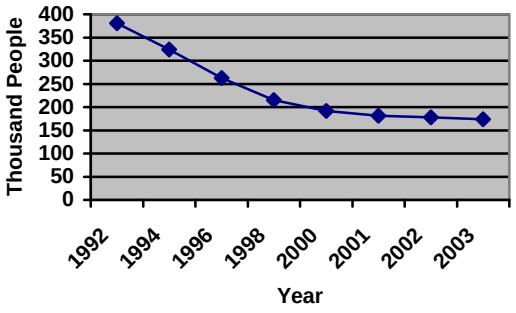
The S&T Workforce

From the period of Soviet rule and to this day, Ukraine, boasting a 99.4 percent literacy rate, has been home to a wealth of highly educated specialists.[69] Ukraine's separation from its former high-technology customers in Russia, the country's economic decline, the lack of funding for R&D, a decline in the quality of Ukrainian education, structural problems in the technology sector, an aging scientific community, and a significant brain drain are all factors in the steady decline of the number of scientific personnel in Ukraine since 1990. Overall employment in R&D declined by more than 45 percent from 1992 through 2002, as shown in figure 9.[70] According to some experts, however, the rate of decline had slowed by the mid-2000s.[71] By 2003 industry employed the most R&D personnel (53 percent), while the academy system employed 30.6 percent; education, 8.9 percent; and industry, 7.5 percent. The number of researchers in Ukraine, per 10,000 of the population, declined from 74 in 1992 to 40 in 2003.[72]

The amount of funding for each researcher is very low in Ukraine, with the R&D budget per researcher half of that in Russia, nearly 4 percent of that in South Korea, and 2 percent of that in France and the United States.[73] Figure 10 compares the amount of funding per researcher in the world's largest innovation economies.

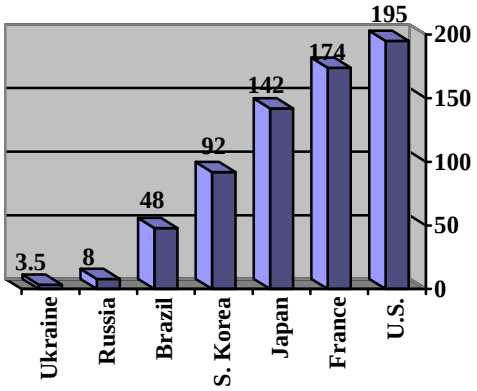
[68] Pischeyko et al, *Millenium Development Goals*.
[69] CIA, "Ukraine."
[70] "Science, Technology and Innovation System in Ukraine."
[71] Yegorov and Voitovych, "A Science Profile," 13.
[72] Yegorov and Voitovych, "A Science Profile," 14.
[73] "Science, Technology and Innovation System in Ukraine."

Figure 9. Ukraine: R&D Personnel, Selected Years, 1992–2003



Source: Based on information from "The Science, Technology and Innovation System in Ukraine," Internationale-kooperation.de, July 2005, http://www.internationale-kooperation.de/doc/ukraine_Final%5B1%5D_1553.pdf (accessed July 26, 2007).

Figure 10. Funding per Researcher, 2002 (in US$)



Source: Based on information from Igor Yegorov and Artem Voitovych for Kyiv Information Services, "A Science Profile of Ukraine," British Council Ukraine, July 2004, http://www.britishcouncil.org/ukraine-science-profile-eng.pdf.

Most scientific researchers and research work are concentrated in the three most developed of Ukraine's 24 administrative regions: Kiev (one-third of all researchers), Kharkov (17 percent), and Donetsk (7.6 percent).[74] Most researchers still are employed by the state, an issue of some concern. In 2003, 84 percent of researchers worked for the government; 10 percent, in higher educational establishments; and 6 percent, in business.[75] Broken down according to scientific discipline, data indicate that most of Ukraine's researchers are in the

[74] Yegorov and Voitovych, "A Science Profile," 10–11.
[75] "Science, Technology and Innovation System in Ukraine."

engineering field (more than 50 percent in 2003, down from 74 percent in 1991), followed by science (19 percent), health and food (15 percent), social sciences (5 percent), humanities (1.5 percent), and education (less than 1 percent). The number of researchers engaged in engineering has been falling throughout the 2000s, while all other fields, except education, have shown some growth. Moreover, pay is declining. In 2003, 10 percent of Ukrainian researchers lived below the poverty line, 50 percent could afford only basic necessities, and only 8 percent had any savings.[76]

Ukraine's Brain Drain

Mass emigration of the most talented and qualified professionals is a major cause for concern because of the impact on Ukraine's economic development, as well as the threat to global security. In late 2004, estimates of the loss to Ukraine's economy attributable to brain drain amounted to US$20 billion.[77] In a 1995 report, Igor Yegorov, a specialist on the Ukrainian science sector, described the three types of brain drain affecting the Ukrainian scientific community: conventional, internal, and hidden.

According to Dr. Yegorov's model, conventional brain drain involves emigration to foreign countries. Dr. Yegorov's data indicate that nearly one-third (22,000) of specialists from the R&D sector left Ukraine between 1988 and 1992, in search of higher paid work suited to their background and training. These emigrants, mostly physicists, biologists, and, from late 1992, specialists from the MIC and the nuclear energy industry, generally were bound for Russia. The Yuzhonoye Design Bureau, Ukraine's premier producer of intercontinental ballistic missiles (ICBMs) reportedly lost a number of its personnel to the United States and Israel.[78] Because of this emigration pattern, Ukraine lacks personnel to support its own nuclear sector, even in 2008.[79]

Internal emigration involves movement of specialists from the S&T sector to other sectors of the Ukrainian economy. Whereas this affects the S&T sector, it also relieves pressure

[76] "Science, Technology and Innovation System in Ukraine."
[77] Volodymyr Senchenko, "Ukraine's Brain Drain," *The Ukrainian Observer* (Kiev), no. 201 (November 2004), http://www. ukraine-observer.com/articles/201/528 (accessed August 23, 2007).
[78] Stacy Larsen, *An Overview of Defense Conversion in Ukraine*, 14 (Bonn: Bonn International Center for Conversion, 1997), http://www.bicc.de/publications/papers/paper09/paper9.pdf (accessed July 19, 2007).
[79] Yegorov, "Transformation of R&D Potential in Ukraine."

on the state budget and on research facilities. Dr. Yegorov states that internal emigration of specialists may help the Ukrainian economy overall.[80]

Dr. Yegorov finds of particular concern hidden emigration, when a scientist formally retains his R&D position but takes on additional employment in other economic sectors. Because institutes and design bureaus often lack work, employers are unable to pay employees and encourage them to take long unpaid leave, forcing employees to seek other work. In 2002, 57,300 specialists held two or more jobs, twice the number of specialists that held more than one job in 1991.[81]

The Age Crisis in the S&T Sector

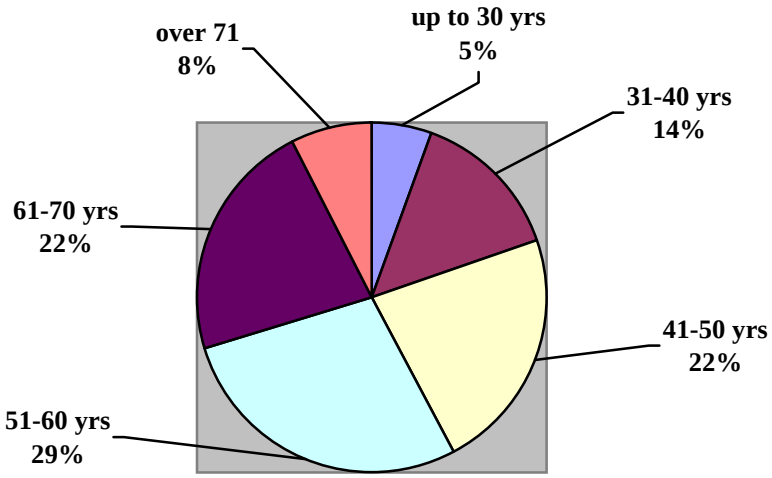
Ukraine's science sector also is plagued by an age crisis, a huge deficit in the number of scientists in the 30 to 50 age range, a cohort that usually performs the most significant R&D work throughout the world.[82] In 2003 the average age for researchers in Ukraine was 50. More than half of Ukrainian Candidates of Sciences (equivalent to a PhD) and more than 80 percent of Doctors of Sciences (equivalent to a senior research fellow) were over 50, while the average age of professors was 60.[83] See figure 11 for a breakdown by age of Ukrainian scientists. In addition, many young scientists choose careers outside research or emigrate after defending their dissertations, because of inadequate salaries, lack of opportunities, or the draw of business.[84] Thus, according to "A Science Profile of Ukraine," Ukraine has established a practice of scientific planning and personnel training, based not on state S&T priorities but on the availability of researchers.[85] According to Lawrence Goldberg, a senior engineering adviser at the U.S. National Science Foundation, academy and university administrators and senior researchers

> see the need to have closer collaboration between Academy researchers and university faculty to attract more young people to science, and to develop career

[80] Yegorov, "Transformation of R&D Potential in Ukraine."
[81] Yegorov, "Transformation of R&D Potential in Ukraine"; and Yegorov and Voitovych, "A Science Profile."
[82] Yegorov and Voitovych, "A Science Profile," 12.
[83] "Science, Technology and Innovation System in Ukraine."
[84] Yegorov and Voitovych, "A Science Profile," 11.
[85] Yegorov and Voitovych, "A Science Profile," 61.

opportunities for new graduates by placing emphasis on technology transfer and development of new small and medium-size innovation companies.[86]

Figure 11. Economically Active Scientists (Candidates and Doctors of Science) in Ukraine, by Age, 2006



Source: Ukraine, State Statistics Committee of Ukraine, *Ukraine in Figures 2006* [*Ukraina u tsifrakh 2006*], Kiev, 2007, 161.

Joint Programs to Employ Former WMD Scientists

Approximately 10 percent of Ukraine's scientists, technicians, and engineers formerly were involved in developing WMD for the Soviet Union. These scientists developed missile technologies, ballistic missile guidance systems, biological weapons technology, nuclear weapons, and chemical weapons.[87] The United States and the countries of the EU have security concerns regarding the conventional emigration of these specialists to other countries, in search of higher pay and work in their specialized fields. As a result, the EU and the United States have worked with the Ukrainian government to set up several programs to help these specialists find meaningful work in Ukraine.

[86] Lawrence S. Goldberg, "Science and Technology Development and Reform in Ukraine," Issue Paper, Civilian Research and Development Foundation, October 31, 2005, 1, http://www.crdf.org/usr_doc/4-Goldberg-eng.pdf (accessed November 26, 2007).
[87] Science and Technology Center in Ukraine, "R&D Partnerships Newsletter 1," June 2003, http://www.stcu.int/documents/publications/Archive/R&D_Partnerships_Newsletter_1.pdf (accessed July 11, 2007).

Science and Technology Center of Ukraine

One of the more successful such programs is the Science and Technology Center of Ukraine (STCU), an intergovernmental organization established by agreement of Ukraine, Canada, Sweden (later replaced by the EU), the United States, and Japan. The center has sister centers in Azerbaijan, Georgia, Moldova, and Uzbekistan. The STCU began operations in December 1995, with the objective of "retaining the expertise of those scientists formerly engaged in military research and development, facilitating economic transition, and preventing brain drain to potentially unstable countries and to make peaceful profitable contributions to global R&D."[88] STCU programs aim to increase Ukrainian research and design capabilities.[89] Since 1993 private companies and government agencies from the EU, United States, and Canada have used the STCU to manage more than 1,000 R&D projects, worth more than US$160 million, and to support more than 12,000 scientists.[90] STCU is the second largest source of R&D funds in Ukraine, after the National Academy of Sciences.[91]

Civilian Research and Development Foundation

The Civilian Research and Development Foundation (CRDF) is a nonprofit organization, authorized by the U.S. Congress and established in 1995 by the U.S. National Science Foundation, that promotes international scientific and technical collaboration through grants, technical resources, and training, for the countries of the former Soviet Union. CRDF's mission is to

- provide cooperative research and development (R&D) opportunities that enable scientists and engineers to address critical security, economic, education and other societal needs;
- advance peace and prosperity by funding civilian research and development projects that contribute to global nonproliferation objectives;
- promote the application of science and technology to economic growth through international partnerships and training that foster invention, innovation, entrepreneurship and the commercialization of technology; and

[88] Larsen, *Overview of Defense Conversion*, 9–10.
[89] Larsen, *Overview of Defense Conversion*.
[90] "Science and Technology Center in Ukraine," Science and Technology Center in Ukraine, http://www.stcu.int/ (accessed July 13, 2007).
[91] Larsen, *An Overview of Defense Conversion*.

- strengthen university research and education in science and engineering.[92]

A US$5 million Nunn–Lugar allocation initially funded CRDF. George Soros then matched the fund, with an additional US$5 million grant to the U.S. National Science Foundation. CRDF has its base in Arlington, Virginia, with offices in Moscow and St. Petersburg, Russia; Kiev, Ukraine; and Astana, Republic of Kazakhstan.[93]

International Association for the Promotion of Cooperation with Scientists from the New Independent States of the Former Soviet Union

The International Association for the Promotion of Cooperation with Scientists from the New Independent States of the former Soviet Union (INTAS) joined with the Ukrainian government in 1995 to jointly fund and organize nonmilitary scientific research proposals for joint research projects with other INTAS member countries. INTAS funds projects at US$4.2 million, and the Ukrainian government matches the sum. The goal of the Ukraine–INTAS program is collaborative research among research teams from Ukraine, member states of the INTAS General Assembly, and other newly independent states of the former Soviet Union (NIS) on mutually beneficial projects. INTAS has finalized 64 projects, mostly in the earth sciences, environmental sciences, energy, and agriculture. The INTAS General Assembly includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the UK.[94] The EU voted to discontinue INTAS at the end of the Sixth Framework Program. INTAS has been in liquidation since January 1, 2007, and, at the time of this writing, was winding up its activities.[95]

Grant Assistance Program: Nonproliferation Program Support

The Grant Assistance Program (GAP): Nonproliferation Program Support assists programs advancing the transition of former weapons scientists into the civilian sector, by facilitating R&D collaborations, not involving weapons research, with U.S. research institutions, companies, and universities. Since 1998 GAP has facilitated nonproliferation-targeted projects

[92] "About CRDF," U.S. Civilian Research and Development Foundation, http://www.crdf.org/about/.
[93] "About CRDF."
[94] Larsen, *Overview of Defense Conversion*, 12.
[95] "INTAS in Liquidation," International Association for the Promotion of Cooperation with Scientists from the New Independent States of the Former Soviet Union (INTAS), http://www.intas.be/.

exceeding US$85 million, engaging more than 3,500 former weapons scientists in Armenia, Azerbaijan, Georgia, Kazakhstan, Moldova, Russia, and Ukraine. GAP also helps the U.S. Department of Energy's program, Initiatives for Proliferation Prevention (IPP), supporting collaborative, civilian-oriented research, involving former weapons scientists, U.S. national laboratories, and U.S. industry.[96]

State Fund of Fundamental Studies of Ukraine

Using contributions from the Ukrainian state budget, as well as from businesses and individuals, the State Fund of Fundamental Studies of Ukraine provides financial support for the research activities of scientific establishments and organizations; higher educational establishments; and particular scientists in the areas of humanities, environmental sciences, and engineering sciences. Specifically, the fund provides support for fundamental research, initiative research, the establishment of scientific centers, research equipment, S&T information acquisition and dissemination, and scientific libraries, as well as supporting the research of young scientists, international research cooperation, conferences, seminars, workshops, congresses, and symposia in which Ukrainian scientists participate.[97]

Capital and Information Assets

The effectiveness of S&T activities also depends on the material and technical endowment of research organizations. The severe reduction in funding for scientific research in Ukraine since the breakup of the Soviet Union has included cuts in funding for research equipment. Whereas during Soviet times Ukraine housed nearly 20 percent of the experimental equipment of the Soviet Union, today the Ukrainian R&D sector suffers from a huge shortage of operational, up-to-date equipment and facilities. According to reports, approximately 85 percent of equipment at the Ukraine Academy of Sciences' institutes is worn out or outdated or both. Other estimates indicate that barely 2 percent of research equipment in Ukrainian S&T establishments conforms to world standards. Modern computers also are rare, and student access to computer resources is limited. Since funding for basic research is not likely to increase in the

[96] "Our Key Focus Areas," U.S. Civilian Research and Development Foundation, 2007, http://www.crdf.org/focus/focus_show.htm?doc_id=290096 (accessed July 19, 2007).
[97] Yegorov and Voitovych, "A Science Profile," 27–28.

near term, some experts have suggested that Ukrainian scientists enter into collaborative arrangements with foreign counterparts, to gain access to modern instrumentation and computing facilities.[98] The largest share of the R&D institutes' expenditures is for labor wages; only about 5 percent of R&D budgets go to equipment purchases.[99]

In addition, R&D institutes have a difficult time obtaining adequate research space. In 2001 Ukrainian research organizations owned 17.6 million square meters of research space but leased approximately 6 percent of this space for nonscientific purposes. In fact, leasing of space is a source of funding for research establishments, while newly created public scientific establishments are unable to find affordable space.[100]

Access to worldwide scientific information is also a problem. The number of scientific titles published in Ukraine has decreased, particularly in engineering and the natural sciences. Since gaining its independence, Ukraine has failed in its attempts to acquire information from the world's leading scientific libraries. However, the country has acquired a limited number of foreign titles through exchange. In addition, many scientific establishments in Ukraine, especially those in outlying areas, have insufficient access to the Internet.[101]

Research Organizations

In the Soviet Union, most scientific research occurred at state or quasi-state branches of Soviet academy institutes, while universities performed pedagogical functions, preparing specialists to work in research facilities. All industry institutes and design bureaus were subordinate to Soviet ministries or branches of All-Union institutes.[102] Ukraine has built its current national scientific system on the leftover Soviet structure, including numerous research institutes, higher education establishments, design bureaus, enterprise scientific and engineering departments, and professional associations.[103]

Many experts agree that the system needs change. According to Gerson Sher, president of the United States Industry Coalition (USIC) nonprofit organization and founding president of the U.S. Civilian Research and Development Foundation (CRDF),

[98] Badrak, "Ukraine Gambles on Technologies."
[99] "Science, Technology and Innovation System in Ukraine"; and Yegorov and Voitovych, "A Science Profile," 36.
[100] Yegorov and Voitovych, "A Science Profile," 15.
[101] Yegorov and Voitovych, "A Science Profile," 15.
[102] Yegorov and Voitovych, "A Science Profile," 4.
[103] Yegorov and Voitovych, "A Science Profile," 2.

> The overwhelming dominance of the academy system, paralleled by the relative weakness of universities as centers of high-quality research and education, is at this time a key challenge that has been noted by many in Ukraine and that bears on Ukraine's ability to allocate research resources rationally and to address a key 'shortfall' of Ukrainian researchers in the 30 to 50 year age bracket.[104]

By 2006 the number of organizations performing scientific R&D totaled 1,510, according to the Ukrainian national statistics organization. Most of these institutions fall under the administration of the National Academy of Sciences of Ukraine (NASU), the Ministry of Industrial Policy, or the Ministry of Education and Science.[105]

Research organizations are dispersed unevenly throughout Ukraine, with the heaviest concentration in the most economically developed regions. In 2001 more than 25 percent of all Ukrainian S&T organizations were in the capital region (Kiev city and province); more than 15 percent of research organizations were in the Kharkov region, home to the well-known Antonov aircraft factory; 7 percent of Ukraine's researchers were in Dnepropetrovsk, where the main industries are mining, machinebuilding, metallurgy, and food processing; and more than 6 percent of researchers were in the Donetsk region, which ranks first in Ukraine in industrial output (20.1 percent of GNP). Overall, these four regions accommodated more than half (almost 55.4 percent) of all research organizations in the Ukraine in 2001.[106]

System of State Academies

The main function of the academy sector is to conduct fundamental and applied research. Ukraine's academy sector consists of six academies of science:

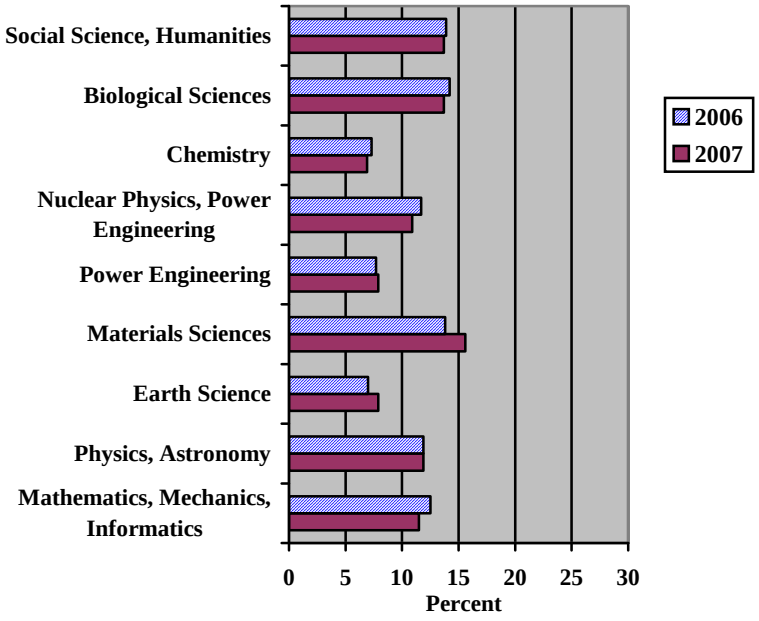
- National Academy of Sciences of Ukraine (NASU)
- Academy of Agrarian Sciences of Ukraine (AASU)
- Academy of Medical Sciences of Ukraine (AMSU)
- Academy of Pedagogical Sciences of Ukraine (APNU)
- Academy of Legal Sciences of Ukraine (ALSU)

[104] Sher, "Role of International Collaboration."
[105] Ukraine, State Statistics Committee, "Statistical Information, 1995–2006.
[106] *Ukraine's Regions* (London: GlobalSecurity Foreign and Commonwealth Office, 2000), http://www.globalsecurity.org/military/library/report/2000/ukraine.pdf (accessed October 30, 2007); and Yegorov and Voitovych, "A Science Profile," 10.

- Academy of Arts of Ukraine (AMOU)[107]

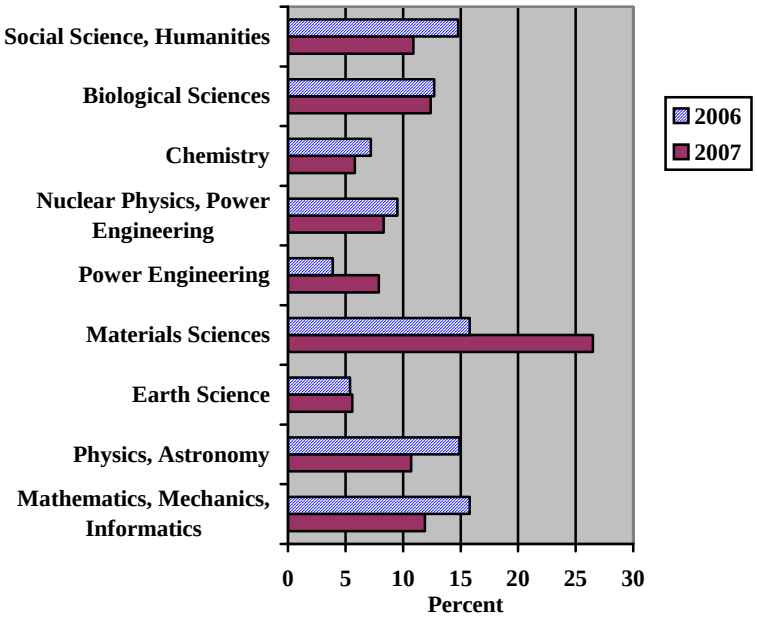
These academies are public research organizations, state owned and financed. The government allows the academies a certain amount of independence in research topics, structure, organization, logistics, personnel, and the implementation of international scientific collaborative arrangements. However, the academies must cooperate with public authorities on issues concerning S&T policy and must report annually to the Cabinet of Ministers of Ukraine on their work and use of state funds. Currently, the academies receive nearly 50 percent of state budgetary R&D funds.[108] See figures 12 and 13 for a graphical depiction of the distribution of NASU's funding in 2006 and 2007 among different scientific sectors.

Figure 12. Distribution of NASU Funding from Ukraine State Budget, 2006–7



[107] Yegorov and Voitovych, "A Science Profile," 10.
[108] Yegorov and Voitovych, "A Science Profile," 39.

Figure 13. Distribution of NASU Funding from Other Sources, 2006–7*



*Other sources include: national programs, contracts from Ukrainian ministries and administrative departments, and private-sector contracts.

Sources: Lidiya Kavunenko and Tatyana Goncharova, "International Cooperation of Ukraine: Barriers on the Way to Equal Integration" (paper presented at International Workshop on Webometrics, Informetrics and Scientometrics and Seventh COLLNET Meeting, Nancy, France, May 2006), http://eprints.rclis.org/archive/00006350/01/ukraine.pdf (accessed September 30, 2008); Ukraine, National Academy of Sciences of Ukraine, "National Academy of Sciences of Ukraine, Brief Annual Report 2006," http://www.nbuv.gov.ua/science/2006_en.pdf (accessed September 30, 2008); and Ukraine, National Academy of Sciences of Ukraine, "National Academy of Sciences of Ukraine, Brief Annual Report 2007," http://www.nbuv.gov.ua/science/2007_en.pdf (accessed September 30, 2008).

NASU, based in Kiev, with branches in cities throughout Ukraine, conducts more than 50 percent of all basic research in the country. NASU comprises three sections: physics, engineering, and mathematics; chemical and biological sciences; and social sciences. The academy has 13 departments, nearly 170 institutes, 2 national libraries, 2 publishing houses, and employs more than 13,000 researchers. NASU scientists have been responsible for more than 90 percent of all new discoveries made in Ukraine, including the transmutation of lithium into

helium, the production of heavy water, and the development of a 3D radar, operating in the decimeter range.[109]

NASU concerns itself with vital national problems. For example, NASU has participated in developing the "Energy Strategy of Ukraine for the Period to 2030 and Beyond," as well as increasing the effectiveness of the state system of monitoring the natural environment, using cutting-edge information technologies, telecommunication systems, and remote Earth sensing.[110]

NASU also provides considerable research support for industry. Yegorov and Voitovych provide a list of some of its projects, as follows:

- Reuse of liquid slag from the melting and treatment of metal fusions in the cast iron and steel industries
- An experimental geothermal heat-and-power line for the Autonomous Republic of Crimea
- Highly productive new varieties of winter wheat
- New composite, polymeric, and chemical materials
- Intellectual software and hardware capable of recognizing voice and image signals
- Intensified mine methane extraction
- Effective plant growth adjustors
- The first domestically produced pesticide[111]

NASU is taking a number of steps to exploit and market its country's research achievements, working on a unified information center to provide information on applied research conducted by its institutes, and an Innovation Center, within the National Institute of Strategic Researches. In addition, 15 planned regional innovation companies within the Ukrainian State Company will be privately owned with access to local bank capital and the funds of the National Bank of Ukraine.[112]

[109] "National Academy of Sciences of Ukraine," Interacademy Panel on International Issues, 2005–2007, http://www.interacademies.net/?id=4296 (accessed July 19, 2007).
[110] Yegorov and Voitovych, "A Science Profile," 44.
[111] Yegorov and Voitovych, "A Science Profile," 44.
[112] Badrak, "Ukraine Gambles on Technologies."

Institutes of Higher Education

According to the report of Ukraine's Ministry of Education and Science, Ukraine has 2,931 institutes of higher education. Most institutes specialize in business studies, including management (151), accounting (122), finance (101), and economics (86). Technology-oriented institutes, specializing in such fields as automated management of engineering processes (37), engineering technology (29), and computer systems and networks (27), are fewer.[113] Institutes specializing in the fields of medicine and biotechnology rank even lower, at 21 and five institutes, respectively. In 2000 about 11 percent of all research activities in Ukraine involved higher education establishments carrying out scientific research and experimental developments.[114]

Technoparks

In the early 1990s the Ukrainian government established technological parks (technoparks) as special economic zones based on certain NASU institutes and universities and their associated experimental and production facilities. The aims of technoparks were: to help Ukrainian scientific institutes accelerate technology development; to integrate science, industry, and society; to accelerate the commercialization of scientific discoveries; and to attract new financial resources to upgrade scientific equipment. The technoparks received government financial support, targeted subsidies, and tax privileges, including relief from import duties and value-added taxes on imported raw materials, equipment, and components. Instead of paying taxes toward the state budget, the government permitted technoparks to transfer the equivalent sum to a special account for further scientific R&D and related infrastructure improvements.[115]

In 1994 the Ukrainian government established the first technopark, financially backed by the EU, in the city of Brody on the site of a former missile base. However, the park's resources were stolen or misused and, by the mid-1990s, local businessmen and their Polish partners had

[113] Ukraine, Ministry of Education and Science, "Number of Higher Educational Institutions by Specialities," http://www.education.gov.ua/pls/edu/educ.chr_specialities_eng.show (accessed July 13, 2007).
[114] Yegorov and Voitovych, "A Science Profile," 57.
[115] Igor Yegorov, "Innovation Policy and Problems of Creation and Development of the National Innovation System in Ukraine (paper presented at the Second Session of the UNECE Team of Specialists on Innovation and Competitive Policies, Geneva, February 14–15, 2008), 14, http://www.unece.org/ceci/ppt_presentations/2008/ic/YegorovPaper.pdf.

converted the park into a large warehouse.[116] In July 1999, the Ukrainian parliament passed the *Law of Ukraine On Special Regimes of Investment and Innovation Activities for Technological Parks* and subsequently established three technoparks in 2000:

- E.O. Paton Institute of Electric Welding in Kiev
- Institute of Monocrystals in Kharkov
- Institute of Semiconductor Technologies and Materials, Optoelectronics and Sensors in Kiev[117]

By 2004 another 13 technoparks had developed:

- Agrotechnopark in Kiev
- Coal Machine (Uglemash) in Donetsk
- EKO–Ukraine in Donetsk
- Institute of Technical Thermal Physics in Kiev
- Intellectual Information Technologies in Kiev
- Kiev Politechnik in Kiev
- Machinebuilding Technologies in Dnepropetrovsk
- Resources of the Donbass in Donetsk
- Scientific and Educational Equipment in Sumy
- Textile in Kherson
- Ukrainian Microbiological Center of Synthesis and New Technologies in Odessa
- Ukraine Information Technologies (Ukrinfotex) in Kiev
- Yavoryv in the Lvov region[118]

According to NASU historian Yegorov, not all of these technoparks were based on institutions or organizations with "real S&T and innovation potential" but on "forced decisions, lobbied by the influential politicians and businessmen."[119]

By early 2005, almost all the privileges afforded to technoparks had been abolished, leading to stagnation in technoparks' development. As of early 2008, only eight of the original 16 technoparks had restarted their business activities. (See Appendix A for a list of the eight Ukrainian technoparks that are currently operating, and their areas of activity.) Yegorov

[116] Yegorov, "Innovation Policy and Problems," 14.
[117] Yegorov, "Innovation Policy and Problems," 14.
[118] Yegorov, "Innovation Policy and Problems," 14.
[119] Yegorov, "Innovation Policy and Problems," 15.

attributes this to the fact that the other eight "simply had no time and reason to commence operations following the ban on their special treatment." Moreover, he says, some had not even completed their formation.[120] Yegorov considers only the Paton Welding Institute and Monocrystal Institute to be successes. In fact, between 2000 and 2006 these two parks produced 98 percent of all innovation products produced at Ukraine's technoparks.[121] However, Yegorov points out that no new innovation projects were registered in technoparks between 2005 and 2006.

At the beginning of June 2007, the Ukrainian parliament held the first hearings of a new law on technoparks (Law N1064-V). The new law addresses the issues of IPR, the rights and responsibilities of technopark management, definitions of the basic elements of technoparks, and eliminates custom duties on the import of new equipment and raw materials not produced in Ukraine.[122] However, Yegorov stated in early 2008, "it is unclear when it will pass into state law as Ukraine is involved into the conflict between major political parties."[123]

TECHNOLOGIES

Ukraine has a well-developed scientific and industrial base. In fact, several areas of the economy demonstrate a high level of technological development. The country produces carrier rockets, satellites, and space research equipment, as well as military equipment, including tanks, military transport aircraft, surface-to-air missile (SAM) complexes, and optical equipment. The Antonov aircraft, walking excavators, precise machinery, and electric welding equipment produced in Ukraine use state-of-the-art technologies that comply with top world standards.[124]

Fuel and Energy Technologies

Energy security is an important issue in Ukraine. A large share of Ukraine's primary energy comes from nuclear power (14 percent) and coal (24 percent). Most of the remainder is

[120] Yegorov, "Innovation Policy and Problems," 15.
[121] Yegorov, "Innovation Policy and Problems," 14–15.
[122] Yegorov, "Innovation Policy and Problems," 15.
[123] Yegorov, "Innovation Policy and Problem," 15–16.
[124] "Ukraine Defense Industry," GlobalSecurity.org, http://www.globalsecurity.org/military/world/ukraine/industry.htm (accessed October 2, 2007).

from oil (12 percent) and gas (49 percent), mostly imported from Russia.[125] Currently, Ukraine provides only 30 percent of its own natural gas; it must purchase the remaining 70 percent from other countries.[126] Ukraine anticipates a major increase in the demand for electricity, to 307 billion kilowatt-hours (kWh) per year by 2020, and 420 billion kWh by 2030; the government's policy is to continue supplying half of this electricity from nuclear power.[127]

While Ukraine remained a Soviet state and until 2005, Russia heavily subsidized energy supplies to the country. However, in late 2005 and early 2006, Ukraine and Russia argued over natural gas price increases, with the result that Russia cut off natural gas deliveries to Ukraine. Ukraine resolved this matter, concluding a deal with Russia that nearly doubled the price it previously had paid for Russian gas. Because of its shortage of domestic energy resources and reliable, affordable international supplies, Ukraine views the development of new energy sources and energy-saving technologies as a high priority.

The Ukrainian Cabinet of Ministers established fuel and energy technologies as major priorities for innovative development for the period through 2013. Plans for developing these technologies include modernization of power plants; development of new and renewable energy sources; and development of new resource-conserving technologies in energy generation, mining, metallurgy, welding, machinebuilding, and agricultural production.[128] These new technologies include emission-proof coal mining; effective techniques for fighting unpredicted discharges of coal, rocks, and gas; high-performance coal mining from thin and inclined beds; incineration of ash-rich, low-grade coal in a circulatory boiling layer; and breakthrough gas-fuel equipment. Ukraine is pursuing alternative energy sources, including thermal waters, geothermal energy for heating, seasonal solar energy and heat accumulation, biofuels, wind, hydroelectricity, and methane conversion.[129]

High energy prices also affect crucial energy-intensive Ukrainian industries, such as chemical, mining, and metallurgy industries, making them uncompetitive. In September 2007,

[125] United States, Department of Energy, Energy Information Administration, "Ukraine, Background," 2007, http://www.eia.doe.gov/emeu/cabs/Ukraine/Background.html.
[126] "Ukrainian Cabinet Cuts Gas Import Boosting Energy Security—Minister," Ukrainian Television UT1 (Kiev), September 24, 2007 (Open Source Center report no. CEP20070925950091).
[127] Australian Uranium Association, "Nuclear Power in Ukraine," Briefing Paper no. 63, Uranium Information Centre, October 2007, http://www.uic.com.au/nip63.htm.
[128] Interfax (Moscow), "Interfax Business Law Review for 21–28 January 2003," January 28, 2003 (Open Source Center report no. CEP20030129000026).
[129] Yegorov and Voitovych, "A Science Profile," 32.

Ukrainian Fuel and Energy Minister Yuriy Boyko advised metallurgical enterprises to modernize production and introduce energy-saving technologies to release working capital for other projects.[130] Therefore, Ukrainian scientists have implemented a range of projects aimed at saving fuel in manufacturing and public utilities, such as

> flat-flame gas rings for heating of industrial furnaces, which ensure more effective heat exchange, decreases fuel consumption by 15 to 20 percent, and cuts hazardous emissions in half. Another energy-saving technology developed in Ukraine cuts energy costs by 20 to 30 percent by means of module stream radiation and convection recuperators to make use of the heat from waste gases emitted by industrial furnaces.[131]

According to Minister Boyko, from 2006 to 2007 Ukrainian consumption of natural gas dropped. He attributed the decrease to a warm winter and to energy savings from the use of turbo-expanders, increased coal extraction, and coal-based energy generation.[132]

Nanotechnologies

The January 2003 law, *On Priority Areas of Innovation Activities in Ukraine*, specifies nanotechnologies as a strategic area for Ukraine S&T during the period 2003–2013.[133] Ukraine hopes that, with the help of nanotechnologies, the country can reduce its dependence on scarce, import-replacing substances and materials, including strategically significant metal imports.[134] Many specialists argue that while Ukraine has achieved "significant success" in the nanotechnology field, it has "made no progress in the introduction of these developments into manufacturing."[135]

Nonetheless, the Science and Technology Center of Ukraine (STCU) claims that Ukrainian scientists working in the field of nanotechnologies have had significant achievements. For example, the NASU institutes have used nanotechnologies to develop new materials with applications in ceramics (miniaturized multilayer condensers) and have produced super-hard carbon films for application in the friction units of recording and reading equipment.[136] STCU

[130] Interfax (Moscow), "Ukraine Targets New Energy Agreements With Russia," Interfax oil and gas report, June 7–13, 2007 (Open Source Center report no. CEP20070614003003).
[131] Yegorov and Voitovych, "A Science Profile," 32.
[132] "Ukrainian Cabinet Cuts Gas Import."
[133] "Science, Technology and Innovation System in Ukraine."
[134] Yegorov and Voitovych, "A Science Profile," 33.
[135] Badrak, "Ukraine Gambles on Technologies."
[136] Yegorov and Voitovych, "A Science Profile," 33.

has approved funding for a project "to develop nanostructured relaxor ferroelectrics, which could improve the characteristics and prices of sensors, actuators and transducer devices." This technology has applications in human health and the security sector. In addition, through STCU the U.S. Air Force has financed a project with the Institute of Solid State Physics (Uzhgorod, Ukraine) and the Institute of Physics (Kiev) to "examine the optical properties of relatively new crystals" used in optical and near-infrared laser applications.[137] Ukrainian scientists have also developed, or are in the process of developing, other nanotechnologies, including

- miniaturized multilayer condensers;
- a new type of semiconductor scintillator for high-speed, high-dosage, x-ray introscopes, tomographs, and dosimeters;
- new methods of obtaining nanocomposites, based on electroconductive polymers;
- matrix, electroconductive, polymeric, anticorrosion coatings;
- modified scandium alloys, based on aluminum;
- organic luminescent materials with new properties;
- basaltic fibers, fabrics, and composites; and
- high-quality, heat-resistant, high-strength materials for export and for domestic consumption in the aircraft and vehicle manufacturing industries.[138]

STCU had funded 30 nanotechnology projects as of 2005.[139] Appendix B profiles some key institutes in Ukrainian nanotechnology research.

In the international arena, Ukraine is pursuing collaborative agreements with Russia, the EU, and the United States for research in nanotechnologies. In August 2007, Russia and Ukraine signed a memorandum in which both sides agreed "to rivet special attention to the need to strengthen scientific and technical interaction between the two countries and create common high-tech projects in nanotechnology and their use in machinebuilding, medicine, rocket and missile engineering, aircraft building and shipbuilding."[140] During a visit to Philadelphia in September 2005, Ukrainian president Viktor Yushchenko stressed the importance of building a

[137] Valentyna Gatash, "Million Dollars on Financing of Joint Projects," *Dzherkalo Tizhnya* (Kiev) 33, no. 612, September 2–8, 2006, http://www.stcu.int/documents/publications/Current/Mass_Media_Articles_2006.pdf.
[138] Yegorov and Voitovych, "A Science Profile."
[139] Science and Technology Center in Ukraine, "Nanotechnology," 2005, http://www.stcu.int/documents/publications/Current/NanoTechnology_2005.pdf (accessed July 17, 2007).
[140] ITAR–TASS (Moscow), "Ukraine's Party of Regions, United Russia Sign Memo on Coop," August 4, 2007, (Open Source Center report no. CEP20070804950118).

large-scale, cooperative program between the United States and Ukraine in the field of nanotechnology.[141] The EU is also working with Ukraine, providing co-funding for research in nanotechnologies and nanosciences, under the EU Sixth Framework Program.[142]

Biotechnologies

In addition to nanotechnology, the January 2003 law, *On Priority Areas of Innovation Activities in Ukraine*, specifies biotechnology as a strategic area for Ukraine S&T during 2003–2013, specifically for research in microbe biotechnologies; plant biotechnologies for biosafety; new medicines, new technologies and techniques for diagnosis and treatment of common diseases; and genetic and analytical biotechnologies.[143] Biotechnology priorities in Ukraine center on the fields of agriculture, medicine, and the environment.[144] The Ministry of Agriculture and the Ministry of Science and Education are responsible for biotechnology research in agriculture; the Ministry of Environmental Protection is responsible for environmental aspects of biotechnology.[145] Since the mid-1990s, Ukraine has had significant development in biotechnology fields. From 1993 to 1994, the share of biotech applications filed with the Ukrainian patent office (Ukrpatent) was 1.5 to 2 percent; from 1996 through 2000, biotech applications increased to 4 to 5 percent of all applications. Overall, Ukrpatent granted 300 patents for biotech inventions between 1993 and 2000.[146]

On June 21, 2007, the government of Ukraine adopted a new law on biotechnology, the *Law of the State System of Biosafety in Creating, Testing, Transporting and Using Genetically Modified Organisms*. Nonetheless, in the opinion of a U.S. Department of Agriculture specialist on Ukrainian agriculture, Ukraine still "has no functioning biotech approval and regulatory system." Until they do, according to this expert, "Ukraine will continue to operate without a

[141] "News Archives (2005)," Nano Materials Group, Drexel University, September 30, 2005, http://nano.materials.drexel.edu/news2005.html.
[142] Ralf König, *European Research Programmes—Funding Opportunities for Ukraine and Moldova* (Vienna: Austrian Research Promotion Agency, Division for International Research and Technology Cooperation (BIT), 2004), http://www.idm.at/veranstaltungen/koenig.pdf (accessed July 25, 2007); and "Science, Technology and Innovation System in Ukraine."
[143] "Science, Technology and Innovation System in Ukraine."
[144] Yegorov and Voitovych, "A Science Profile," 33–34.
[145] Food and Agriculture Organization of the United Nations, "Biotechnology Country Profiles—Ukraine," Rome, 2007, http://www.fao.org/biotech/inventory_admin/dep/country_rep.asp?country=UKR.
[146] A. Pakharenko-Anderson, "Building up Biotech in Ukraine," Managing Intellectual Property, June 2003, 1, http://www.managingip.com/Article.aspx?ArticleID=1255719.

functioning system to regulate, test, and approve biotech products." However, Ukraine has committed to "establishing a functioning approval and regulatory framework for biotech products" as a precondition to World Trade Organization (WTO) membership, expected in 2008.[147] The scientific community and the government have experienced some dissent on the efficacy of biotech products, and this remains a very sensitive issue. However, observers consider it likely that "biotech believers" in the government and the scientific community will push through legislation on biotechnology.[148]

Agriculture

Ukraine, a major food producer while a Soviet republic, retains significant agricultural potential. For this reason, Ukrainian scientists, specifically scientists of the National Academy of Sciences of Ukraine have concentrated on the Ukrainian agriculture sector's priority scientific developments. Ukrainian scientists' recent biotech developments include

- acclimatization of plants;
- radiobiology;
- hydrobiology;
- biology space and gravitation;
- rational use of resources of living nature, environment, and biodiversity;
- new varieties of high-quality, high-yield winter wheat, rye, corn, triticale, soy, fruit, feed, spices, vegetables, and floral cultures; and
- increased viability and productivity of numerous agricultural plants.[149]

Medicine

Ukrainian biotechnology efforts in the medical field have resulted in the discovery of new medicines and biologically active substances, as well as improved diagnostic methods in the treatment of human disease. Ukraine is among three ex-Soviet countries where the number of human immunodeficiency virus (HIV)–infected people exceeds 1 percent of the adult population

[147] Olena Pereyatenets, *Ukraine Biotechnology Agricultural Biotechnology Report 2007* (Washington, DC: U.S. Department of Agriculture, 2007), http://www.fas.usda.gov/gainfiles/200707/146291695.pdf (accessed September 25, 2007).
[148] Pereyatenets, *Ukraine Biotechnology*.
[149] Yegorov and Voitovych, "A Science Profile," 34.

(the other two are the Russian Federation and Estonia). In the other countries of the region, this indicator was less than 0.3 percent. The World Health Organization (WHO) has recognized Ukraine as a leader in introducing measures for preventing mother-to-child transmission of HIV. Tuberculosis (TB) is another medical concern in Ukraine. In Russia and Ukraine, 40,000 persons die from TB every year, 20 cases per 100,000 of population, while for EU member states this number is less than 10 per 100,000.[150]

One notable achievement in the medical sphere is a tissue-bonding procedure developed in Ukraine and patented in Australia, Canada, the EU, Ukraine, and the United States. NASU's E.O. Paton Institute of Electric Welding invented and developed this technique for bonding and reconnecting living soft biological tissue through fusion, instead of by means of conventional wound-closing devices, such as sutures, staples, sealant, or glues. CSMG Technologies, Inc., a Texas-based technology management company, which finances, owns, develops, licenses, and markets innovative advanced technologies and business opportunities created in Ukraine, has bought this technology and the exclusive world rights to use it.[151] Three Ukraine hospitals use the technology daily for open and laparoscopic surgical procedures and techniques in the nasal septum, intestines, stomach, skin, gall bladder, liver, spleen, blood vessels, nerves, alba linea, uterus, fallopian tubes, ovaries, and testicles.[152] The Sumy State Biofactory is a leading manufacturer of biological factors in Ukraine.

In 2006 Ukraine's bilateral contacts in the medical sphere increased significantly. Health care issues, particularly the fight against HIV/acquired immune deficiency syndrome (AIDS), TB, and avian influenza, are among the priorities of the Ukraine–United States bilateral relationship. The U.S. Agency for International Development (USAID) Strategy for HIV/AIDS Preparedness in Ukraine for 2003–2008 supports cooperative efforts in the fight against HIV/AIDS. The Strategy for HIV/AIDS Preparedness has tackled a number of projects to intensify information exchange on HIV/AIDS–related issues and to overcome discrimination against people who are HIV-infected or ill with AIDS. To overcome the TB pandemic, the U.S. government has assisted Ukrainian programs, providing short-term antituberculosis therapy. The WHO implements the program, along with the PATH company and the Futures Group

[150] Pischeyko et al, *Millenium Development Goals*.
[151] "Tissue Engineering; CSMG Technologies, Inc. Announces Ukraine Tissue Welding Patent Issued," *Biotech Week*, July 25, 2007, 904 (accessed September 26, 2007 via Proquest).
[152] "Live Tissue Bonding Technology," CSMG, 2007, http://www.csmgtechinternational.com/live_tissue_bonding.html.

International. The United States also assists in combating the spread and fighting the consequences of avian influenza in Ukraine. Ukraine is eligible for funds up to US$975,000 for influenza preparedness and response, under a June 2006 U.S. government pledge of more than US$334 million in grants to assist a number of countries in fighting avian influenza.[153]

Weapons

Since its independence in 1991, Ukraine has not been engaged in either offensive or defensive biological weapons activities. However, under the Soviet regime, some Ukrainian antiplague research facilities were involved in biological warfare activities, for the most part defensive activities. The United States provides aid to Ukraine to improve security at facilities housing dangerous microbes. One lab to receive funding is the I. I. Mechnikov Antiplague Scientific and Research Institute, in the Black Sea port city of Odessa. The institute was part of a Cold War network of antiplague stations supplying highly lethal pathogens to Soviet bioweapons factories.[154] Currently, Ukraine does not possess biological weapons, continuing to cooperate with the United States on physical protection upgrades at research institutes housing dangerous pathogens.[155] However, *Jane's Sentinel Security Assessment* reports that the Biochemistry Institute of NASU was an implementing agency of the Soviet biological warfare program and may still have stocks of the toxins developed and produced for that program.[156]

An STCU brochure on biotechnology points out that the help of former biological weapons scientists could prove valuable in developing the Ukrainian economy:

> As biology continues to evolve into an integrated, quantitative science with application in many industrial sectors, the expertise of chemical-biological scientists and engineers that were formerly engaged in the development and/or delivery of weapons of mass destruction (WMD) should not be overlooked. There exists a vastly untapped resource for development and commercialization.[157]

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[153] Ukraine, Ministry of Foreign Affairs, Embassy of Ukraine to the United States of America, "About Ukraine: Science and Technology Cooperation," http://www.mfa.gov.ua/usa/en/1688.htm (accessed July 11, 2007).
[154] Joby Warrick, "U.S. to Aid Ukraine in Countering Bioweapons," *Washington Post*, August 30, 2005, http://www.washingtonpost.com/wp-dyn/content/article/2005/08/29/AR2005082901728.html (accessed September 25, 2007).
[155] Center for Nonproliferation Studies, "NTI: Country Overviews: Ukraine: Profile," Nuclear Threat Initiative, April 2006, http://www.nti.org/e_research/profiles/Ukraine/index.html (accessed July 13, 2007).
[156] "Ukraine/Armed Forces," *Jane's Sentinel Security Assessment—Russia and the CIS*, 2005 (accessed July 23, 2007 via Intelink).
[157] Science and Technology Center in Ukraine, "Biotechnology," 2006, http://www.stcu.int/documents/publications/current/Biotechnology_Ukraine_2006.pdf (accessed July 17, 2007).

Appendix C lists Ukraine's key biological research organizations.

In the mid-1990s, Western governments and international organizations began involving Ukrainian biological research facilities and biological research scientists in cooperative projects. These international activities include assistance and support with

- collaborative research aimed at preventing scientists from selling their expertise to terrorist groups or proliferating states, and encouraging them to use their knowledge for peaceful purposes;
- biosafety enhancement, to make facilities safer workplaces; and
- biosecurity improvement, to consolidate and restrict unauthorized persons' access to pathogens.[158]

A number of organizations and programs in the United States and Europe support these projects, including the following:

- Nuclear Threat Initiative (NTI)
- U.S. Cooperative Threat Reduction Program (CTR)
- U.S. Department of Health and Human Services (DHHS) Biotechnology Engagement Program (BTEP)
- U.S. Department of Energy's Initiative for Proliferation Prevention (IPP)
- Civilian Research and Development Foundation (CRDF)
- Science and Technology Center in Ukraine (STCU)
- EU nations, through bilateral agreements, according to the G8 Global Partnership Against the Spread of Weapons and Materials of Mass Destruction
- European Community Technical Assistance for the Commonwealth of Independent States (TACIS)
- European Union Joint Action on Nonproliferation and Disarmament in the Russian Federation
- International Association for the Promotion of Cooperation with Scientists from the Independent States of the Former Soviet Union (INTAS)
- European Union's INCO–COPERNICUS
- Netherlands Organization for Scientific Research (NOW)
- German Academic Exchange Service (DAAD)

[158] Center for Nonproliferation Studies, "NTI: Ukraine."

- United Kingdom Royal Society[159]

Chemical Industry

Improvement in chemical technology and new materials is a priority for innovative development by 2013, as established by the Ukrainian Cabinet of Ministers. The Ukrainian chemical sector includes chemical, petrochemical, and chemical/pharmaceutical sub-sectors. The chemical sector encompasses more than 1,600 enterprises and structural units, accounting for nearly 10 percent of Ukraine's industrial fixed assets, and employing more than 5 percent of Ukraine's industrial workers. Some 90 percent of these capital assets and about 80 percent of these employees work in the chemical sector itself, with substantially fewer capital and human assets involved in petrochemicals and pharmaceuticals.[160]

Ukraine has manufactured various kinds of chemical products for many years. The sector began developing as an industry in the late 1800s, mostly producing dyes, soda, super phosphates, and the like. Until its independence from the Soviet Union in 1990, Ukraine produced 25 percent of the Soviet Union's soda ash, 24 percent of its plant-protection chemicals, 18 percent of its sulfuric acid, 16 percent of its mineral fertilizers, 16 percent of its caustic soda, and 13 percent of its chemical fibers.[161] Today Ukraine's chemical sector produces mineral fertilizers, nonorganic acids, and soda, as well as synthetic resins, plastics, chemical fibers, caoutchouc (an elastic material obtained from the latex sap of trees), and fibers.[162] Appendix D lists Ukraine's main chemical research organizations.

Before 1991 the Soviet government stored and tested chemical weapons in Ukraine. In addition, the Soviet army conducted experimental chemical weapons tests in the Black Sea, near the Ukrainian cities of Odessa and Sevastopol. Chemical weapons stockpiles and storage bases were located in the cities of Fastov, Ochakov, and Zolotonosha, Ukraine.[163]

Since it gained independence in 1991, Ukraine has not engaged in either an offensive or defensive chemical warfare (CW) program, nor does it have any published plans to develop chemical weapons. However, Ukraine does have the industrial infrastructure to do so without

[159] Center for Nonproliferation Studies, "NTI: Ukraine."
[160] Ukraine, State Property Fund of Ukraine, "Chemical and Petrochemical Industry," UkraineGateway, http://www.ukraine-gateway.org.ua/gateway/gateway.nsf/webcontent/05020300 (accessed October 10, 2007).
[161] Ukraine, State Property Fund of Ukraine, "Chemical and Petrochemical Industry."
[162] Ukraine, State Property Fund of Ukraine, "Chemical and Petrochemical Industry."
[163] Ukraine, State Property Fund of Ukraine, "Chemical and Petrochemical Industry."

major modifications to plants and machinery. In January 1992, Russian president Boris Yeltsin declared the move of all former Soviet chemical weapons to Russia. However, according to *Jane's Sentinel Security Assessment* "it is understood that Kiev does possess 'very large quantities' of non-persistent weapons for riot control" and that Russian forces based in Ukraine "have a stockpile of non-persistent battlefield NBC agents."[164] Ukraine is a state party to the Chemical Weapons Convention (CWC), which it ratified in 1998, and it joined the Australia Group in April 2005.[165]

Information and Communications Technology

In 2002, in a report by Harvard University's Center for International Development, a Ukrainian information technology (IT) company executive characterized Ukraine's information and communications technology (ICT) sector as having a number of "powerful" software firms and a "sufficient number of IT specialists." However, he noted that the sector is lacking in investment and startup capital, computer infrastructure, and telecommunications, and is using an obsolete analog telephone network.[166] Other impediments to the development of Ukraine's ICT sector, according to the report, are a nascent e-commerce industry, hampered by the lack of online payment systems; an underdeveloped electronic security system; poor protection of intellectual property rights; a lack of specific Internet regulation; and insufficient PC and Internet penetration throughout the country. Since 2000 the Ukrainian government's ICT priorities have included improving the national telecommunications infrastructure, as part of its bid for EU membership; privatizing Ukrtelecom, the state-owned telecommunications company; and improving ICT literacy and education.[167] Wireless services have grown quickly, because of the high installation costs and long waiting periods for fixed telephone lines. However, the high costs of operation make mobile services affordable only to a small proportion of the population.[168] Foreign investment in the private sector has facilitated the growth of the Internet

[164] "Ukraine/Armed Forces."
[165] Center for Nonproliferation Studies, "NTI: Ukraine."
[166] Alzhan Braliev and Yuri Onisimov, "Global Competitiveness Report 2001–2002, Country Profiles: Ukraine," Harvard University Center for International Development, February 2002, http://www.cid.harvard.edu/cr/profiles/Ukraine.pdf (accessed July 12, 2007).
[167] Braliev and Onisimov, "Global Competitiveness."
[168] Braliev and Onisimov, "Global Competitiveness."

in Ukraine.[169] See figures 14 and 15 for a comparison of the number of Internet hosts and Internet users in the EU, Russia, Ukraine, and the United States in 2006.

Figure 14. Comparison of Internet Hosts, 2006

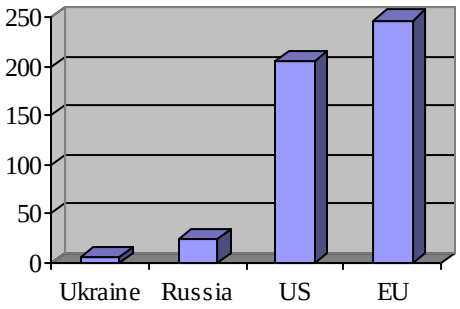
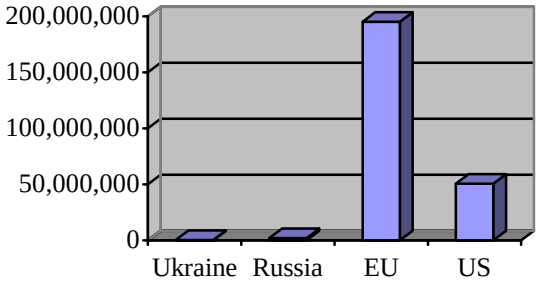


Figure 15. Comparison of Internet Users, 2006



Source for both figures: CIA, "Ukraine," *World Factbook* (Washington, DC, 2007).

Ukraine's national strategy for ICT is laid out in the government white paper, "Information Communication Technologies and the Internet," which defines the goals of Internet development in Ukraine as follows:

- Build up of sufficient economic, legal and technical conditions for the provision of broadband Internet access to citizens, educational establishments, scientific and other organizations of any property form, state and local authorities and entrepreneurs;
- Expansion and advancement of objective political, economic, legal, ecological, scientific, cultural and other relevant e-contents that are elaborated by the State and local

[169] Braliev and Onisimov, "Global Competitiveness."

authorities, educational establishments, scientific and cultural organizations, archives, libraries, museums etc, concerning Ukraine's development;

- Improvement of legislation and regulatory framework to enable the key players in the ICT market, dealing with production, implementation, distribution and storage of electronic information, to operate effectively and efficiently, including further improvement of the protection of intellectual property rights;
- Enhancement of access to both national and international information resources;
- Ensuring citizens' constitutional rights to free accumulation, storage, use and distribution of information, and freedom of speech and expression;
- Development and introduction of modern computerized technologies in the system of the public administration, financial sphere, entrepreneurial activity, education and, finally, provision of legal aid;
- Guaranteeing State support of infrastructure development aimed at the provision of on-line services;
- Provision of affordable access to broadband Internet and other relevant information resources and services to educational establishments, scientific organizations, NGOs, as well as to museums, libraries, other cultural and medical establishments, including those situated in rural areas;
- Guaranteeing security of information and protection of consumers;
- Formation and further advancement of information resources.[170]

Military Technologies

Ukraine inherited about 30 percent of the Soviet military industry, which at the time encompassed 50 to 60 percent of all Ukrainian enterprises. GlobalSecurity.org, an online source of information and news on defense, space, intelligence, WMD, and homeland security, describes the Ukrainian MIC as "the most advanced and developed branch" of Ukraine's economy. Furthermore, the site gives the following account of scientific and research organizations involved in research, design, and production in Ukraine's MIC:

- Armaments and military equipment—85 scientific organizations
- Air and space research—8 design bureaus, 64 enterprises
- Ships and armaments for the Ukrainian navy—15 R&D institutes, 40 design bureaus, and 67 plants

[170] *Towards a Knowledge-Based Economy: Ukraine Country Readiness Report*, 10–11.

- Rockets, missiles, projectiles, and other munitions and related equipment—6 design bureaus, 28 plants
- Small arms—an unspecified number of scientific-industrial corporations
- Armor—3 design bureaus, 27 plants
- Military communications and automated control systems—2 scientific-research institutes, 13 plants
- Power supply batteries—2 scientific-research institutes, 53 plants
- Intelligence and radio-electronic warfare equipment—3 scientific-research institutes, 6 plants
- Engineered equipment and matériel—4 design bureaus, 27 plants

As it was during the Soviet period, Ukraine remains a leader in missile-related technology, especially guidance systems, navigation electronics for combat vessels and submarines, and radar for military jets.[171]

Ukrainian technology experts believe their country also could develop a competitive advantage in the following fields:

- Space
- Aviation and aviation engine-building
- Armored tank and armored vehicle engine-building
- Shipbuilding, including the creation of remote-controlled underwater vehicles
- Updating modern military hardware
- Optoelectronics
- Navigation devices
- Self-homing heads for ground-to-air and air-to-air missiles and artillery shells;
- Radio-engineering control stations
- Sound-metric systems for artillery reconnaissance
- Complex control systems
- Radio communication devices
- Radio-electronic warfare means
- Unmanned flying devices

[171] "Ukraine Defense Industry," GlobalSecurity.org, http://www.globalsecurity.org/military/world/ukraine/industry.htm (accessed October 2, 2007).

- Aviation and missile homing systems

More recently, Ukraine technology shows promising development in the fields of nanoelectronics, super-high-speed data transfer, IP-telephony, the creation of light super-durable materials, and heterogeneous surfaces welding. However, despite Ukraine's R&D strengths in these fields, Ukrainian companies have made little progress in commercializing these developments.[172]

Today, production by the MIC accounts for 37 percent of Ukraine's GNP,[173] and the Ukrainian leadership wants to transform the MIC into a high-tech, science-intensive industry.[174] So far, with the help of private funding, enterprises of the Ukraine MIC reportedly have made progress in developing competitive special technologies and equipment, such as information technologies; active and passive (including thermal) millimeter-wave technologies; visible, short- and long-range optoelectronic systems; various types of radiolocation systems; rocket technologies; and aviation technologies.[175] For example, under diversification programs, Open, Joint Stock Company (OJSC) Motor-Sich, Design Bureau Progress, Central Design Bureau Arsenal, Design Bureau Luch, and Research Institute Kvant-Radiolocation are said to have invested their own funds in applied science and in new developments conforming to world standards.[176]

Sensors

Ukraine has had some success in patenting military-purpose sensor technologies, such as the updated 36D6 radar station (19 patents), Kolchuga passive reconnaissance radar station (five patents), and the Kvitnyk laser artillery shell with semi-active, self-homing head (one patent).[177] Ukrainian scientists also have significant achievements in laser micro-engraving, a dual-use technology.[178]

[172] Badrak, "Ukraine Gambles on Technologies."
[173] CIA, "Ukraine," *World Factbook.*
[174] Yegorov and Voitovych, "A Science Profile," 34.
[175] Yegorov and Voitovych, "A Science Profile," 34–35.
[176] Yegorov and Voitovych, "A Science Profile," 35.
[177] Badrak, "Ukraine Gambles on Technologies."
[178] Badrak, "Ukraine Gambles on Technologies"; and "Strategic Weapons/Section 5—Former Soviet Union/CIS, East and Central Europe," *Jane's Strategic Weapons—De-Militarisation Markets*, January 1, 2005 (accessed via Intelink).

Companies and organizations with significant sensor capabilities include Dnepropetrovsk Machinebuilding Factory, Elsys Electronic Systems, Aerotechnica Ltd., Kvant design bureau, Special Radio Device Design Bureau public holding company, Topaz holding company, and the Donetsk National Technical University, all profiled in Appendix E.

In 2001 the Kvant design bureau announced its Kashtan–3 optoelectronic countermeasure, capable of detecting laser beams of targeting systems and leading laser-guided bombs and missiles away from their targets using a false laser spot. Although at that time Kvant claimed that there were no analogous systems in the world, apparently two other companies, the French company Sagem and the UK company Marconi, were developing similar systems but had not yet produced them. Because its work was secret, Kvant had not exported its products, except to Russia, until 1997. However, in 2001 the bureau's director claimed that half of Kvant's production was exported to such countries as China and South Korea, and that Pakistan also had expressed interest in acquiring the Kashtan–3. Kvant also was considering joint research with Russia to develop a Russian Kashtan.[179]

The Kolchuga–M, a new-generation, strategic, long-range, passive radar complex is one of Ukraine's success stories in the sensor field. Kolchuga–M was Ukraine's entry into the world of high-tech radio-electronics and, at least as of 2004, the Kolchuga had no analogous rivals in Brazil, the Czech Republic, France, Russia, or the United States. Because of its success, one of Kolchuga's developers, the Special Radio Device Design Bureau, was able to increase its staff fourfold, between 1996 and 2004, and to expand its fields of research. The relatively cheap Kolchuga–M provides early warning, locating communications and navigation signals and radar emitters from land, sea, or air platforms, including stealth aircraft.[180] The Kolchuga–M also detects takeoff and formation of aircraft at ranges beyond those of existing radar.[181] The Russians first developed Kolchuga systems in the 1980s. In the 1990s, the Special Radio Device Design Bureau public holding company, Topaz, and the Donetsk National Technical University

[179] BBC Worldwide Monitoring, "Ukrainian Design Bureau Offers New Air Defence Technology to Russia," December 17, 2001 (Open Source Center report no. CEP20011213000042).
[180] "U.S. Sees Ukraine Radar as Major Upgrade for Iraq's Air Defenses," World Tribune.com, December 6, 2002, http://www.worldtribune.com/worldtribune/WTARC/2002/me_iraq_12_06.html.
[181] Robert Karniol, "Ukraine Sells Kolchuga to Iran," *Jane's Defence Weekly*, September 27, 2006 (accessed via Intelink).

modernized the Kolchuga, with financing from the Ukrainian Defense Ministry, via Ukrsketsexport investment bank and Prominvestbank.[182]

The export of the Kolchuga to China, Ethiopia, Iran, Iraq, and, possibly, North Korea has created considerable international controversy. In 2002 the United States was concerned about the reported sale of four Kolchuga systems to Iraq through Jordan and the subsequent discovery of another sale of four Kolchuga systems to China.[183] In 2006 controversy once again arose after the reported sale of an unknown quantity of Kolchuga systems to Iran. That same year, Ukrainian officials confirmed the sales to China, continuing to deny sales to Iran, Iraq, and Ethiopia.[184]

Missiles

The Ukrainian Soviet Socialist Republic was a key missile and subcomponents manufacturer during the Soviet era.[185] When the Soviet Union dissolved, Ukraine inherited significant ICBM design and production capabilities, including the Yuzhnoye (Pivdenne) Design Bureau, which designed the SS–18 and the SS–24 ICBMs, and the Yuzhmash (Pivdenmash) Machinebuilding Plant, which produced a wide range of Soviet ICBMs, including the SS–18 and SS–24. During the Soviet era, the Yuzhnoye complex, with its innovative ICBM design and production facility, rivaled some U.S. and Russian missile enterprises. Today, the Yuzhmash plant produces nonmilitary goods such as space boosters, trolleybuses, and washing machines. However, financial strain reportedly has led the plant to explore other production bases. Among these are arms and technology transfer arrangements with China and Iraq, development of a missile with a range of up to 500 kilometers, and conversion of retired military missiles for use as space launchers.[186]

Ukraine has other missile facilities dating from the Soviet period, including the Luch State Design Bureau, the main developer of Ukrainian guided missiles;[187] the Pavlohrad

[182] Volodymyr Horbulin, "A Country Capable of Creating the 'Kolchuga' Can Look Into Future with Confidence," *Zerkalo Nedeli* (Kiev) 34, no. 509 (August 28–September 3, 2004), http://www.mw.ua/3000/3100/47574/.
[183] Horbulin, "A Country Capable of Creating the 'Kolchuga'.
[184] Peter Felstead, "Kolchuga to China Not Iran, Ukrainian Officials Say," *Jane's Defence Weekly*, October 11, 2006 (accessed via Intelink).
[185] Douglas Barrie, "Chinese Fireworks," *Aviation Week and Space Technology* 161, no. 18 (November 8, 2004): 57 (accessed via Proquest).
[186] Larsen, *Overview of Defense Conversion*.
[187] Badrak, "Ukraine Gambles on Technologies."

Chemical and Mechanical Plants, involved in ICBM manufacture; and the Khartron Production Association, producer of guidance systems. These enterprises have engaged in a variety of space projects, including converting SS–18 ICBMs to space launch vehicles (SLVs) in cooperation with Russian firms, participating in the international Sea Launch program, and cooperating with Russian enterprises on new SLV designs.[188]

Although no ballistic missiles are currently in production, Ukrainian facilities continue to produce SLVs and their components. Ukraine possesses Tsiklon and Zenit rocket types and reportedly continues to work on new variants. In addition, Ukrainian firms are working on a project to convert retired SS–18 ICBMs into Dnepr SLVs for use in commercial space launches from Russia. Ukraine hopes to preserve much of its rocket industry, which it regards as the most important high-tech sector of its economy, but because of the acute crisis of its economy, the country's ability to provide necessary funding is limited.[189]

Ukraine's missile industry is noteworthy, in that its facilities originally were developed as components of a much larger missile and space industry, dispersed throughout the Soviet Union. As a result, whereas Ukraine inherited outstanding capabilities in some areas, it is lacking in many other areas. For example, the programmatic decisions made in Moscow concerning the direction of the Soviet rocket industry left Ukraine without its own rocket launch facilities, except for the ballistic missile silos of the Strategic Rocket Forces deployed in its territory. Therefore, Ukraine's missile industry is the product of a somewhat random collection of facilities that happened to be located within Ukrainian territory when the Soviet Union broke up. Ukraine has shown no indication that it plans to exploit the considerable potential of its missile industry for military purposes,[190] nor has the country attempted to continue ballistic missile production or to modernize the ballistic missiles deployed in its territory.[191]

Although Ukraine has attempted a number of joint projects with Western countries, most of these projects have collapsed, leaving Russia Ukraine's most important partner in this field and the sole source of funding for many missile enterprises.[192] Because Ukraine's missile industry was part of the former Soviet missile industry, it still relies heavily on cooperation with its Soviet-era partners in Russia. Russian companies are involved in virtually all of Ukraine's

[188] Center for Nonproliferation Studies, "NTI: Ukraine."
[189] Center for Nonproliferation Studies, "NTI: Ukraine."
[190] Center for Nonproliferation Studies, "NTI: Ukraine."
[191] Center for Nonproliferation Studies, "NTI: Ukraine."
[192] Center for Nonproliferation Studies, "NTI: Ukraine."

rocket programs and international ventures. Russia also remains heavily dependent on cooperation with Ukraine, because the Russian Strategic Rocket Forces use many missiles, including the SS–18 and SS–24, designed, manufactured, and/or assembled in Ukraine.

Recently, Ukraine has pursued a policy of integration with European and other Western institutions, with the goal of membership in the North Atlantic Treaty Organization (NATO) and the EU. In addition, Brazil is a possible source of financial assistance for the struggling Ukrainian missile industry. The two countries have initiated a joint venture to provide commercial launch services, using converted Ukrainian missiles as launch rockets and Brazil's Alcântara launch facility.[193] In March 2004, Ukraine adopted the Hague Code of Conduct against Ballistic Missile Proliferation.[194] Nonetheless, Russia reportedly has approached Yuzhmash to discuss the viability of restarting ICBM production in Ukraine.[195]

Aviation

In the Soviet era, Ukraine was known for its achievements in aviation, particularly passenger planes, for regional and medium-haul routes, and for trunk-line passenger planes. With few resources to spare, Kiev has had to concentrate its available funds on those concerns that it sees as worth preserving, such as the aviation sector. Today Ukraine is among the top nine countries of the world boasting a full cycle of indigenous aviation hardware engineering and production. Improvements in the aircraft industry are among Ukraine's priority directions for developing its economy. In 2007 the Ukrainian government gave aircraft manufacturing a jump-start, investing nearly US$500 million in the industry. According to Ukraine's Ministry of Foreign Affairs, "development of new projects and Ukrainian aircraft entrance to international markets will only turn profitable after mass production of the mentioned planes begins." The industry is still looking for strategic investors.[196]

Current priority projects in the aviation sector include modernizing Ukraine's MiG–29 fighters and developing the An–70 military transport project, a plane bigger than the C–130s made by the United States. In a May 2007 article in the journal *Kiev Defense-Express*, author

[193] Center for Nonproliferation Studies, "NTI: Ukraine."
[194] Center for Nonproliferation Studies, "NTI: Ukraine."
[195] Center for Nonproliferation Studies, "NTI: Ukraine."
[196] Ukraine, Ministry of Foreign Affairs, "Aircraft and Aerospace Industry," http://www.mfa.gov.ua/data/upload/publication/uk/en/12752/32154.htm.

Andriy Feshchenko stated that if Ukraine's armed forces fail to modernize the MiG, Ukraine will have no fighters left by 2015, when the existing fleet reaches the end of its service life. Feshchenko, suggesting that Ukraine should cooperate with Russia to update the MiG fleet, described the capabilities the future fighters should have.[197] However, the project's future has been in jeopardy since May 2006, when Russia announced its withdrawal from the project.

The Ukrainian aviation sector not only designs and produces passenger and transportation aircraft, but also has a network of aircraft repair enterprises, including repair facilities for military planes and helicopters.[198] Ukraine's main aircraft enterprises include

- Kharkov State Aircraft Manufacturing Company (KhSAMC or KhGAPP), manufacturing passenger, cargo, and military aircraft;
- Antonov Kiev Engineering Plant, producing cargo, multipurpose, and passenger airplanes as well as gliders and hang gliders;
- Lvov State Aircraft Repair Plant (LSARP), repairing and overhauling military-purpose aircraft, including MiG fighter bombers; and
- Motor Sich Joint Stock Company, one of the world's largest aviation engine manufacturers.[199]

Ukraine's main aviation research centers include the Kharkov Aviation Institute, Central Research Institute of Navigation and Control, Antonov Aeronautical Scientific/Technical Complex, Antonov Scientific and Production Complex Design Office, Aviant Kiev Plant, Kharkov Aircraft Manufacturing Plant, Kiev's Aircraft Repair Plant no. 410, Kharkov's FED Machinebuilding Plant, the Buran Institute, and Kharkov Aggregate Engineering Design Office. In addition, Ukraine's aviation research sector includes the following joint-stock companies, profiled in Appendix F: ElectronPribor OJSC, Dnepropetrovsk Aggregate Plant, and the Ukrainian R&D Institute of Aircraft Technology (UkrNIIAT).

During the 2000s, the Ukrainian aviation sector has undergone a series of major reorganizations, including the 2005 creation of the Antonov Corporation. The Antonov Corporation united the Antonov Scientific and Production Complex Design Office, the Kiev and

[197] Andriy Feshchenko, "Critical Angle of Attack: The Modernization Programme for the Mig–29 Fighter for the Ukrainian Armed Forces Risks Coming to a Stop," *Defense-Express* (Kiev), May 31, 2007 (Open Source Center report no. CEP20070608950259; accessed June 14, 2007).
[198] Alexey Komarov, "Commercial Break," *Aviation Week and Space Technology* 162, no. 19 (May 9, 2005): 40 (accessed July 20, 2007 via Proquest).
[199] "Kharkov State Aircraft Manufacturing Company," GlobalSecurity.org, http://www.globalsecurity.org/military/world/ukraine/ksamc.htm.

Kharkov aircraft manufacturing plants, Aircraft Repair Plant no. 410, and UkrNIIAT. However, as of late 2007 the Ukrainian government planned to liquidate the Antonov Corporation, to form a single state-held joint-stock company to build aircraft. The new company will combine several state-owned organizations: Antonov Scientific and Production Complex Design Office, Aviant Kiev Plant, Kharkov Aircraft Manufacturing Plant, Kiev's Aircraft Repair Plant no. 410, Kharkov's FED Machinebuilding Plant, the Buran Institute, and Kharkov Aggregate Engineering Design Office, as well as joint-stock companies, including ElectronPribor OJSC, Dnepropetrovsk Aggregate Plant, and UkrNIIAT.[200] The reorganization is intended to implement a more efficient centralized management system and to provide a single marketing and financial center for the aviation industry.

The international aircraft market faces tight competition, and Ukrainian analysts claim that, if aircraft mass production projects lack significant investment within the next five years, Ukraine is likely to lose its market share to competitors in Brazil, Canada, and Russia. Analysts identify the industry's likely markets as Ukraine's domestic civil and military sectors, as well as Africa, Australia, Europe, India, Kazakhstan, Russia, South America, and Sri Lanka. Ukraine's aviation industry continues to pursue joint projects for mass production with companies from other countries, including the OJSC Aviakor, an aircraft manufacturing plant in Samara, Russia, and the HESA Company in Esfahan, Iran. *Jane's All the World's Aircraft* reports that all planes of Ukrainian origin continue to be produced through international cooperation. For example, the Kharkov state aircraft production enterprise uses piloting and navigational systems, radio equipment parts, and hydraulic units from Russia; fire-prevention equipment from Kazakhstan; elements for domestically assembled components from Azerbaijan; electric equipment parts and cables from Germany and France; seats from Switzerland; and global positioning system (GPS) and traffic collision avoidance system (TCAS) systems from the United States.[201] In 2006 *Aviation Week and Space Technology* reported that France's Thales had concluded a framework agreement with Ukraine's Antonov to integrate Thales Topdeck glass cockpits and Amascos maritime patrol systems into new and existing Antonov aircraft. Thales already supplies

[200] Komarov, "Commercial Break"; and Ukraine, Ministry of Foreign Affairs, "Aircraft and Aerospace Industry."
[201] "Aircraft—Manufacturer/Ukraine/Antonov—Natsional'naya Korporatsia Samolet-Zdani Antonova (Antonov National Aircraft-Building Corporation)/Manufacturer Details," *Jane's All the World's Aircraft*, August 9, 2006 (accessed July 23, 2007, via Intelink).

electrical generation system hardware for An–70s and An–140s.[202] Ukraine also produces ultra-light aircraft such as ultra-light planes, hang gliders, motorized hang gliders, and paragliders, which it exports mostly to Australia, France, New Zealand, the UK, and the United States. In addition, Ukrainian aircraft producers are approaching customers in Asian and African countries, including Egypt, Libya, Pakistan, Saudi Arabia, and the United Arab Emirates (UAE), which are not interested in expensive American and European planes. Iran imports Ukrainian aircraft sets for assembly.[203]

Ukraine is looking to China Aviation Industry Corporation II as a production partner in its Antonov An–70 military airlifter program and its other aviation programs. Antonov already has worked with China Aviation Industry Corporation I, carrying out wind-tunnel tests on its ARJ21 regional jet and contributing to its wing design.[204] Antonov and China's Shaanxi Aircraft also have discussed collaboration on the Chinese Y–8X turboprop-powered military air lifter.[205]

Russia has a major role in upgrading Ukraine's air force, providing communications and fire-control software for the MiG–29 and helping to modernize Ukraine's S–300 (SA–10 Grumble), SA–11 Gadfly (9M38 Buk–M1), and SA–N–4 Gecko (OSA–M) air defense systems. Joint Russian–Ukrainian work to develop new combat systems focuses on "designing weapons based on new principles of physics, developing systems of radio and electronic combat and intelligence and country identification."[206]

Nuclear Sector

Fuel

Ukraine has been exploring uranium since 1944. Some 21 deposits have been discovered in Ukraine, mostly located in south-central Ukraine.[207] Approximately 10 percent of the total

[202] Patricia J. Parmalee, ed., "Thales Inks Antonov Deal," *Aviation Week and Space Technology* 165, no. 5 (July 31, 2006): 17 (accessed July 20, 2007, via Proquest).
[203] Ukraine, Ministry of Foreign Affairs, "Aircraft and Aerospace Industry."
[204] Alexey Komarov, "Chinese Remedy Ukraine Looks to China as Candidate to Replace Russia on the An–70 Airlifter," *Aviation Week and Space Technology* 159, no. 19 (November 10, 2003): 50 (accessed July 20, 2007, via Proquest).
[205] "Shaanxi Aircraft and Ukraine's Antonov," *Aviation Week and Space Technology* 157, no. 20 (November 11, 2002): 21 (accessed July 20, 2007, via Proquest).
[206] "Ukraine/Armed Forces."
[207] "Projects: Ukraine," Uran Ltd, http://www.uranlimited.com.au/UkraineUraniumDeposits.html.

deposits of recoverable uranium ore in the former Soviet republics were located in Ukraine.[208] Today, analysts believe Ukraine is the world's tenth-largest producer of uranium.[209] The state enterprise VostGOK provides about 30 percent of the country's nuclear fuel requirements from two sites in the Dnepropetrovsk region. A VostGOK subsidiary, the Zheltye Vody Mill, is Ukraine's top uranium producer. By 2030 Ukraine plans to increase its annual uranium production by 800 percent.[210] Ukraine also has the potential to develop zirconium production at a special plant in Sumy.[211] Ukrainian president Viktor Yushchenko said on January 13, 2006, that as part of Ukraine's efforts to reduce its reliance on Russia for energy, Ukraine should produce its own nuclear fuel for its power plants, taking control of the "full cycle of processing and production of nuclear fuel."[212]

Because its priority is developing nuclear power, the Ukrainian government has allowed foreign investment in its uranium industry. For example, Russian Uranium Mining Company (UGRK) is assisting Ukraine in its Novokonstantinovsk uranium project at a relatively undeveloped field in the Kirovograd Region. Project engineers expect first production late in 2008, with production reaching 2,500 tons per year by 2020. Experts anticipate that this project could increase production more than fivefold, meeting Ukrainian nuclear power requirements and enabling uranium exports.[213] In another joint venture, in December 2006 Australian-based Uran Ltd. signed a protocol with VostGOK to develop uranium deposits in the Dnepropetrovsk region of Ukraine.[214] In addition, in early 2007, two Canadian companies, Star Uranium Corp, a resource company focused on the strategic acquisition and development of uranium, diamond, and precious metal properties, and United Carina Resources Corp, an exploration company, formed a joint venture to acquire uranium exploration licenses in Ukraine and the former Soviet Union.[215]

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[208] "Strategic Weapons/Section 5."
[209] Rick Walker, "Star Uranium, United Carina form Ukraine JV," United Carina Resources Corp, February 26, 2007, http://www.staruranium.com/index.php?section=news_page&id=45.
[210] "Russia Offers to Invest in Uranium Mining in Ukraine," June 4, 2007 (accessed June 14, 2007, via the Open Source Center); and "Projects: Ukraine."
[211] "Ukrainian President: Development of Nuclear Energy is the Most Politically Integral Issue for the Stability of the Country," Bellona, March 29, 2007, http://www.bellona.org/news/ukranianatom?printerfriendly=yes'.
[212] "Ukraine Wants to Produce Own Nuclear Fuel," Bellona, January 17, 2006, http://www.bellona.org/english_import_area/international/russia/nuke_industry/co-operation/41644.
[213] "Ukraine to Achieve Self-Sufficiency in Uranium by 2013," New Uranium Mining Projects—Europe, WISE Uranium Project, June 15, 2007, http://www.wise-uranium.org/upeur.html#UA.
[214] "Projects: Ukraine."
[215] Walker, "Star Uranium, United Carina."

Although Ukraine has some indigenous uranium-mining operations, it continues to rely heavily on the Russian Federation for enrichment and reprocessing of nuclear waste. Up until now, Ukraine has sent all spent nuclear fuel from Ukrainian reactors to special storage at Krasnoyarsk or the Mayak plant in southern Russia for reprocessing. However, Ukraine prefers to begin storing its nuclear waste domestically. According to the Ukrainian Fuel and Energy Ministry, domestic storage will be 10 times cheaper than transporting waste to Russia. With international assistance, Ukraine will construct a new storage facility at the site of the Chernobyl Nuclear Power Plant, where spent nuclear fuel can be stored safely for a minimum of 50 years.[216]

Power

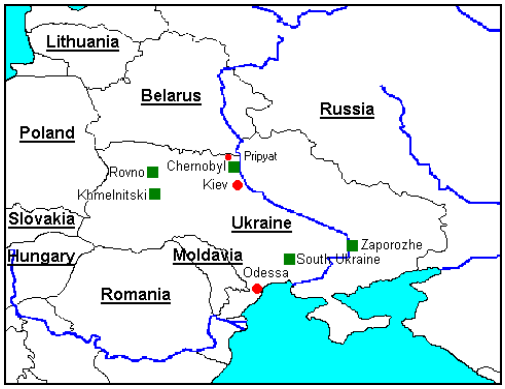
Nuclear power reactors have operated in Ukraine since 1977, when the first unit of the Chernobyl plant began operation. Since the nuclear accident at the plant in 1986, all of Chernobyl's four units have been shut down. The 1986 accident destroyed unit four; unit two halted operation after a fire in its turbine building in October 1991; unit one was shut down in 1996; and unit three was shut down in December 2000.[217] Chernobyl is currently under development as a storage facility for spent fuel. As of 2007, Ukraine operated 15 reactors at four nuclear power complexes—Khmelnitskyy, Rivne, South Ukraine, and Zaporozhzhya. In 2006 Ukraine's nuclear power production equalled 84.8 billion kWh, accounting for nearly 50 percent of total domestic electricity production.[218] See figure 16 for a map of Ukraine's four operating nuclear power complexes, plus Chernobyl.

Faced with rising energy prices and few domestic energy sources, Ukraine continues to pursue nuclear energy as its primary power source. In March 2007, at a conference in the Ukrainian city of Sumy, President Yushchenko stressed that developing nuclear power is "not only a matter of national energy and economic security" but also a "politically integral issue for the stability of the country." Citing continued improvement in the operational safety and output

[216] "Ukraine Not to Ship Spent Nuclear Fuel to Russia," Bellona, June 25, 2001, http://www.bellona.org/english_import_area/international/russia/nuke_industry/co-operation/21148?printerfriendly=yes'.
[217] "Chornobyl Operating History," International Nuclear Safety, February 13, 2001, http://insp.pnl.gov/-profiles-chornobyl-ch_history.htm. In September 2007, Ukraine announced that a French company had won the contract to construct a giant steel cover for the damaged unit 4 reactor. See "Chernobyl to be covered in steel," BBC News online, September 18, 2007, http://news.bbc.co.uk/2/hi/europe/6999140.stm (accessed October 2, 2007).
[218] Australian Uranium Association, "Nuclear Power in Ukraine."

levels of Ukraine's nuclear reactors, the president stated that, in the face of rising energy demands, the Ukrainian government's goal is to double nuclear power output by 2030.[219]

Figure 16. Map of Ukraine's Nuclear Power Plant Complexes



Source: Australian Uranium Association Web site, http://www.aua.org.au/index.php.

Recently, the nuclear sector in Ukraine has undergone reorganization. In March 2007, the Ukrainian cabinet approved a statute for the creation of the vertically integrated state nuclear company Ukratomprom, unifying Ukraine's nuclear companies and organizations. Another purpose of the reorganization was to attract foreign investment "to facilitate the development of the national nuclear fuel cycle."[220] Ukratomprom, subordinate to the Ministry of Energy, is the result of the merger of, among other organizations,

- Energoatom, the national atomic energy utility, which owns and operates Ukraine's 15 reactors;
- VostGOK (Eastern Mining and Concentration Complex) uranium mining company;
- Novokonstantinov uranium development company;
- Turboatom, the main turbine producer for nuclear power plants in the former Soviet Union;
- Smoly State Enterprise, a generator of anion exchangers, cation exchangers, and organic sorbents for softening, desalting, and treating water;
- Research Institute of the Industrial Technologies (RIIT), which provides research, development, and survey support for mining uranium ore, gold, and rare earth metals; is

[219] "Ukrainian President: Development of Nuclear Energy."
[220] "Ukraine Consolidates its Nuclear Industry," World Nuclear News, March 22, 2007, http://www.world-nuclear-news.org/corporate/220307Ukraine_consolidates_its_nuclear_industry.shtml.

involved in the creation of radiation safety systems for the uranium facilities; and is responsible for implementing the Nuclear Fuel Cycle Creation Program in Ukraine;[221] and

- Dnepropetrovsk zirconium tube production plant.[222]

A number of controversies have surrounded the formation of Ukratomprom. Some observers have expressed concern that, by merging these entities, the government removed them from the list of enterprises not subject to privatization and thus could transfer them to the new structure and then sell them as a package. Some suggest that the Ukrainian government designed the new atomic association with the intention that Rosatom, the Russian nuclear utility, would absorb Ukratomprom.[223] In April 2008, the Ukrainian government established Nuclear Fuel Ukraine (NFU), a new organization to direct its nuclear energy complex. Ukratomprom was to be abolished in August 2008. NFU will focus on nuclear fuel production and nuclear fuel cycle development and is composed of all the components of Ukratomprom, except for Energoatom and Turboatom.[224]

Ukraine's plans for its nuclear sector for the next several years include

- a US$1.875 million uranium production venture including refurbishment of VostGOK's hydrometallurgical plant and construction of a uranium mill at Novokonstantinov to begin in 2007;
- a US$1 billion U.S.-sponsored enrichment plant to be completed by 2014;
- 15-year life-extension projects for Rovno 1 and 2 reactors; and
- the construction of 11 new nuclear units, as called for in Ukraine's "Energy Strategy until 2030."[225]

[221] "About Us," Ukrainian Research and Design Institute for Industrial Technology, http://www.iptzw.dp.ua/us/about.htm.
[222] "Ukraine Consolidates its Nuclear Industry."
[223] Irina Khmara, "Chain Reaction of Plots," *Nezavisimaya Gazeta* (Moscow), August 21, 2007 (Open Source Center report no. CEP20070822380001).
[224] "Ukraine's Nuclear Sector Undergoes Another Restructuring as Nuclear Fuel of Ukraine Concern Is Created," Nuclear Threat Initiative, Ukraine, Fuel Cycle Developments, April 17, 2008, http://www.nti.org/e_research/profiles/ukraine/nuclear/3969_4990.html.
[225] Charles Digges, "Ukraine Increasing Nuke Energy Use While Getting Help at Chernobyl," Australian Uranium Association, Bellona, September 25, 2007, http://www.bellona.org/articles/ukraine_fuel; "Ukraine Profile, Nuclear Overview."

Weapons

The Soviet Union formerly carried out approximately 40 percent of its nuclear weapons program in Ukraine. When the Soviet Union collapsed, Ukraine inherited the third largest nuclear weapons stockpile in the world, in addition to a large nuclear infrastructure.[226] According to the Nuclear Threat Initiative (NTI), Ukraine's weapons stockpile included 130 SS–19 and 46 SS–24 ICBMs; 25 Tu–95 and 19 Tu–160 strategic bombers, with air-launched cruise missiles; an estimated 1,900 strategic warheads; and 2,275 tactical nuclear weapons.[227] After the fall of the Soviet Union, Belarus, Kazakhstan, and Ukraine opted to return their weapons and delivery systems to Russia, becoming nonnuclear states. By the end of 1996, Ukraine had transferred all of its strategic and tactical nuclear warheads to Russia and dismantled all strategic bombers on Ukrainian territory, transferred them to Russia, or converted them to nonmilitary use. By early 2002, Ukraine had eliminated, or disassembled to await elimination, all ICBMs and had destroyed all ICBM silos.[228] Ukraine has since joined the Nuclear Nonproliferation Treaty as a nonnuclear weapon state and become a member of the Nuclear Suppliers Group, while Ukraine's Supreme Council has ratified the Comprehensive Test Ban Treaty (CTBT) and the International Atomic Energy Agency (IAEA) Additional Protocol.[229]

International Cooperation

In June 2007, Sergei Kiriyenko, head of the Russian nuclear utility Rosatom, and Andriy Derkach, head of Ukraine state enterprise Ukratomprom, signed a memorandum on cooperation in the nuclear industry. Under this agreement, the nuclear energy agencies of the two countries will cooperate in providing scientific and technical support to the nuclear energy industry; increasing the safety and extending the service life of nuclear reactors; designing and building new nuclear power plants; developing nuclear fuel cycle enterprises; and seeking joint access to third-party markets. The main participants in this activity will be Ukraine's Kharkov Research

[226] "Strategic Weapons/Section 5."
[227] Center for Nonproliferation Studies, "NTI: Ukraine."
[228] Center for Nonproliferation Studies, "NTI: Ukraine: Profile"; and Alexander N. Honcharenko, "Ukraine's National Security and the Future of Military Buildup," in *Defense Conversion, Economic Reform, and the Outlook for the Russian and Ukrainian Economies*, 163–75 (New York: RAND, 1994).
[229] "Ukraine Profile, Nuclear Overview," Nuclear Threat Initiative, September 2007, http://www.nit.orgle_research/profiles/Ukraine/Nuclear/index_3967.html.

Institute Energoproekt and the Russian company Atomic and Energy Machine Building.[230] The agreement will give Russia the right to mine uranium in Ukraine, build nuclear power stations, and manage machinebuilding for the energy sector. In addition, Russia is to transfer to Ukraine technologies for making fuel rods, invest in uranium mining at the Novokonstantinovskoye deposit, and participate in the construction of Khmelnitskiy units three and four.[231] Russia and Ukraine are also ready to operate jointly in the markets of third countries, according to Kiriyenko. Some experts feel that this protocol with Russia marginalizes Ukratomprom, indicating Kiev's acknowledgment that Ukraine cannot develop its nuclear sector on its own.

In September 2007, the Ukraine Nuclear Energy Department of the Ministry of Fuels and Energy reported that Ukraine was considering participating in the international uranium enrichment center project in Angarsk, Russia, perhaps joining by the end of the year.[232] Currently Russia holds a 90 percent stake in the project, while Kazakhstan holds 10 percent. If it joins, Ukraine will receive a portion of the shares.[233] The Angarsk center is a joint-stock, asset-management company, with its main purpose "to provide non-nuclear countries with access to enriched uranium for use as fuel at nuclear power plants, without gaining access to dual-purpose uranium enrichment technology."[234]

To reduce Ukraine's dependence on Russia for fuel supplies, the United States and Ukraine signed a nuclear fuel cooperation agreement in 2000. The Westinghouse Electric Company in the United States produces the only alternative fuel for Ukraine's Russian-designed VVER–1000 reactors. Westinghouse provides fuel, services, technology, plant design, and equipment for the commercial nuclear power industry. The Ukrainian National Security Council has drafted a resolution requesting that the country's Ministry of Fuel and Energy use non-Russian fuel at three of its 15 power blocks before 2011.[235] According to the Norwegian nonproliferation group Bellona, under this agreement the Yuzhna nuclear power plant in

[230] ITAR–TASS (Moscow), "Ukraine, Russia Sign Protocol on Atomic Industry Cooperation," June 4, 2007 (Open Source Center report no. CEP20070604950341; accessed June 14, 2007).
[231] "Summary of Reporting on Russian and FSU Nuclear Issues—06/08/2007," June 8, 2007 (Open Source Center report no. CEP20070612436001; accessed June 14, 2007).
[232] Interfax (Moscow), "Ukraine Considering Affiliation to Angarsk Uranium Enrichment Center," June 4, 2007 (Open Source Center report no. CEP20070604950210; accessed June 14, 2007).
[233] ITAR–TASS (Moscow), "Ukraine May Soon Start Entry into Uranium Enrichment Project," June 22, 2007 (accessed July 16, 2007, via Eastview).
[234] Interfax (Moscow), "Ukraine to Decide on Joining Intl Uranium Enrichment Center by Dec 2007—Official," September 26, 2007 (Open Source Center report no. CEP20070926950188; accessed October 2, 2007).
[235] "Ukraine Increasing Nuke Energy Use While Getting Help at Chernobyl."

southern Ukraine began experimental use in 2005 of six Westinghouse-supplied nuclear fuel assemblies at reactor number three.[236] Ukraine intends to start making regular purchases of Westinghouse fuel for three of its 15 nuclear power units by 2009.[237]

Research

The principal nonmilitary organizations exercising control over nuclear research and engineering are the Ministry of Chernobyl and the State Committee for Nuclear and Radiation Safety.[238]

Space

Under the former system, Ukraine was involved heavily in the Soviet Union's missile and space programs, providing spacecraft and launch vehicle design and production. Today, Ukraine is among the few countries in the world that possesses a complete space rocket production complex.[239] However, Ukraine does not have its own space launch facility, so all launches using Ukrainian rockets take place from facilities in Kazakhstan, Russia, or the Sea Launch platform in the Pacific Ocean. Ukraine apparently has no plans to develop a domestic space launch facility. Kiev retains the potential to manufacture ballistic missiles. However, as of November 2003, there appeared to be little likelihood that Ukraine would resume ballistic missile development or deploy such weapons itself. Ukraine has retained its right to build and deploy short-range, nuclear-capable missiles, should its security be threatened, but no work on such missiles appears to have taken place.[240]

Five-year National Space Programs, implemented by the National Space Agency of Ukraine (NSAU), form the basis of Ukraine's space initiative. NSAU encompasses 30 enterprises, scientific research institutes, and design offices,[241] Ukraine's central executive authorities, and the National Academy of Sciences of Ukraine (NASU).[242]

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[236] "Ukraine Starts Using US Nuclear Fuel," Bellona, August 10, 2005, http://www.bellona.org/english_import_area/international/russia/npps/co-operation/39352.
[237] "Ukraine Increasing Nuke Energy Use While Getting Help at Chernobyl."
[238] "Strategic Weapons/Section 5."
[239] Ukraine, Ministry of Foreign Affairs, "Aircraft and Aerospace Industry."
[240] Center for Nonproliferation Studies, "NTI: Ukraine."
[241] Ukraine, Ministry of Foreign Affairs, "Aircraft and Aerospace Industry."
[242] Yegorov and Voitovych, "A Science Profile," 50.

Independent Ukraine's first space program operated from 1994–97, with its main purpose to preserve "the scientific and production potential in the space industry for the benefit [of the] national economy and [the] security of the country as well as to facilitate Ukraine entering international space services markets."[243] The goals of the second Ukraine space program (1998–2002) were to form a domestic market for space services; to enter the international space market with domestically produced products and services, including rocket complexes and space vehicles, information from space, and space system components; and to integrate Ukraine's space program into the international space community.[244] The most recent Ukraine space program (2003–7) aimed to make effective use in space of Ukraine's S&T and production potential. Specific programs within the 2003–7 national program included:

- *Scientific space research*: Priorities include study of the Earth and the space around it; astronomic and astrophysics ground-space projects; space biology; the physics of weightlessness; establishment of a space-based weather monitoring system; studies of the "space garbage" problem and asteroid danger; and studies of the moon, small bodies, and planets.[245]
- *Remote Earth sensing*: Focus is on improving the efficiency of space facilities for environmental management. Specific programs targeted for development include the space-based Sich and Sich–1M (an R&D satellite) Earth observation systems (the Sich Project); the Sich–2 optoelectronic observation system; the MC–1–TK micro-satellite project; the ground complex for receiving, archiving, processing, and disseminating aerospace data (the Monitoring Project); an information analytical center (the Anticriz project); a Ukrainian network for using aerospace observation data (UMAKS project); and customized, aerospace, remote-sensing technologies (Kosmokarta project).[246]
- *Telecommunication satellite systems*: The Ukrainian space program plans to develop a space segment of the geostationary system satellite communication (Libid–M project); a state satellite broadcasting system (Libid–R project); an international legal framework for national satellite networks (Libid–GSO project); the ground infrastructure for receiving satellite voice and data communications, TV, and radio broadcasting; a state system for

[243] Yegorov and Voitovych, "A Science Profile," 50.
[244] Yegorov and Voitovych, "A Science Profile," 50.
[245] Yegorov and Voitovych, "A Science Profile," 51.
[246] Yegorov and Voitovych, "A Science Profile," 52.

satellite digital broadcasting (TV Signal project); an agency telecommunication network of the integrated service for space infrastructure (Mereja–V project); a space-based navigation project; equipment and technologies to ensure safety of stationary mobile and remote objects by means of space navigation and communication systems (Safety project); an automated system for collecting and processing geophysical information (Geonetwork project); a system to control and analyze space situations, ballistic provision of flights of space vehicles and space systems developed in Ukraine (Observation project); and modernization of existing double-purpose functional centers, complexes, and systems of the NSAU for special information provision (Modernizatsiya–S project).[247]

- *Space complexes*: Priorities in this area include development of launch vehicles, in particular, light carrier rockets, including the Cyclone–4 project, the Cyclone–TE and Cyclone carrier rocket projects; the Zenith–M project; the Dnepro modernization project for ground infrastructure; space vehicles, including the KA Sich–1M and KA–2 Sich projects; and the MC–1–TK and MC–2–8 micro satellites.[248]
- *Developing basic and progressive space technologies:* Projects include space instrument-making (advanced control systems and measuring devices in the Wave, RSA, Prylad, Vymir, and Ros–1–1 projects); propulsion engineering (improving the energy-to-mass ratio and maneuvering capacities of space vehicles, expansion of their functional capacities and increasing their market value under the Polumya, Forsage, Ammiak, and ERDU projects); materials science (innovative construction materials, materials with unique properties, and import-replacing materials in the Krona, Tehma, Technologist, and Ros' projects); and the development of new types of SLVs (Mayak–12 and Mayak–23 programs).[249]
- *Developing the research, experimental, and production framework for the space industry*: Priorities include the development and implementation of new technological solutions aimed at modernizing production and improving product reliability under the Torch, Progress, Stereo, Model, Energy, Kompozit, Automation, and Cluster projects.

[247] Yegorov and Voitovych, "A Science Profile," 52–53.
[248] Yegorov and Voitovych, "A Science Profile," 54.
[249] Center for Nonproliferation Studies, "NTI: Ukraine"; and Yegorov and Voitovych, "A Science Profile."

The main development and production organizations involved in Ukraine's space program are the Yuzhnoye (Pivdenne) Design Bureau and the Yuzmash (Pivdenmash) Production Association located in Dnepropetrovsk. During the Soviet period, both these organizations were responsible for the design and production of many Soviet missiles, launch vehicles, and spacecraft. Ukraine's main space programs use the launch vehicles and engines produced at Yuzhnoye. Yuzhnoye also has instrument and satellite design bureaus, and it designs and builds the Cyclone rockets. The fourth generation of Cyclone rockets features a high-accuracy GPS navigational system and a payload capability of 12,000 pounds for an equatorial orbit at 300 miles.[250] The Yuzhnoye Design Office also produced Zenit, a world-renowned, environmentally safe rocket system with fully automated processes for takeoff and super-precise space injection. The Energy–Buran universal space system (the Soviet/Russian space shuttle) used the first stage of Zenit as a side accelerator. Appendix G lists Ukrainian space-related enterprises and their activities.

Ukraine has signed framework agreements on cooperation in space research with Brazil, China, India, the Russian Federation, the United States, and other countries, in addition to memoranda with 23 other states. Available information suggests the Ukraine–China research collaboration primarily involves exchange of specialists and joint conferences.[251] India has signed a protocol with NSAU, Yuzhnoye (Pivdenne) Design Bureau, the Yuzhnoye (Pivdenne) Machinebuilding Plant, and the Pavlograd Chemical Factory for collaborative research on the development of rocket engines, production of components and devices for space vehicles, and research and production of different types of rocket fuel.[252] Ukraine and Israel also have instituted a formal space research cooperation agreement, although the subjects and form of this cooperation are unknown.[253]

Ukraine and the EU began cooperating in space research in 2003. In a speech at the opening of the joint workshop "Ukraine–Europe Cooperation in Space Research," held in Kiev in January 2004, Roman Shpek, head of Ukraine's mission to the EU, stated that "the main priorities of Ukraine's foreign policy remain the restoration of Ukraine's European identity and

[250] Glenn E. Curtis, "Non-U.S. Space Programs: Ukraine Profile and Potential Contributions to Collaborative Efforts," Federal Research Division, Library of Congress, February 2005, 6.
[251] Mark A. Stokes, "China's Strategic Modernization: Implications For the United States," Federation of American Scientists, September 1999, http://www.fas.org/nuke/guide/china/doctrine/chinamod.pdf.
[252] Yegorov and Voitovych, "A Science Profile."
[253] Wendy Elliman, "Israeli Space Research," Jewish Virtual Library, 2007, http://www.jewishvirtuallibrary.org/jsource/Economy/spaceres.html.

gradual integration into the European political, economic and research area."[254] In this collaboration, Ukraine hopes to integrate its space program with that of the EU, with particular emphasis on the following:

- Development of joint projects aimed at restructuring the Ukrainian space industry, with cooperation in the fields of high technology and industrial conversion
- Development of the Galileo global navigation satellite system, a joint initiative of the European Commission and the European Space Agency. In 2005 Ukraine became the third country outside the EU, after China and Israel, to join the Galileo system. The agreement will provide EU airlines access to the Ukrainian market from any EU member state. In addition, Ukraine has a stake in the Galileo Joint Undertaking, which manages Galileo's development. The Galileo Joint Undertaking will become part of the Egnos GPS wide-area augmentation system that will precede Galileo.[255]
- Cooperation in space science, life sciences, and micro-gravitation, and exploration of Earth from space
- Exchange of information on emergency uses of Earth remote sensing
- Provision of data on monitoring of space environment and seismic observations
- Data sharing received from space vehicles of Ukraine and those of other EU countries, and the exchange of data recieved from satellites
- Joint use of ground-based space infrastructure of Ukraine and other EU countries
- Participation in conferences, symposia, and seminars with a space theme, conducted under the aegis of the EU[256]

Russia is Ukraine's most important foreign partner in the space sector. In addition to the joint activities described above, the two countries have discussed the feasibility of using Ukrainian technology in a Russian research project to explore the moon and Mars. They have discussed the possibility of joint construction of the ground infrastructure for a global satellite navigation system covering Ukraine, Russia, and parts of Europe for the 2012 Ukraine European Football Championship and the 2014 Winter Olympic Games in Russia. Ukraine and Russia also

[254] Ukraine, Ministry of Foreign Affairs, "Speech of Mr. Roman Shpek, Ambassador Extraordinary and Plenipotentiary, Head of Mission of Ukraine to the EU at the workshop 'Ukraine—Europe Cooperation in Space Research,'" Kiev, January 30, 2004, http://www.ukraine-eu.mfa.gov.ua/eu/en/publication/print/2338.htm.
[255] "Ukraine Has Agreed to Become," *Aviation Week and Space Technology* 162, no. 24 (June 13, 2005): 31 (accessed July 20, 2007, via Proquest).
[256] Ukraine, National Space Agency, "Aspects of the Integration Process of Ukraine into the EU," http://www.nkau.gov.ua/nsau/catalogNEW.nsf/mainE/471c5ea33aebbb0fc3256cfc00592072!Open&Lang=E.

have decided to resume regular meetings between specialists at the two countries' aeronautics and space departments and academies of science.[257]

In November 1994, U.S. president William J. Clinton and Ukrainian president Leonid Kuchma signed the "Agreement Between the United States of America and Ukraine on Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes." The agreement identifies the United States' National Aeronautics and Space Administration (NASA) and Ukraine's NSAU as the implementing agencies, specifying the areas of civil space cooperation between the two countries, which are space communications, life and microgravity sciences and applications, and Earth studies.[258]

At the same time that the United States and Ukraine drafted this agreement, NASA and the E.O. Paton Welding Institute in Kiev initiated a joint project called the International Space Welding Experiment. The purpose of this project was the "flight demonstration of the Ukrainian Universal Hand Tool (UHT), an electron beam-welding tool developed by Paton, to assess the capability of the UHT to perform new emergency repairs on the International Space Station."[259]

Ukraine has been aggressively pursuing commercial space ventures with customers abroad in an effort to preserve a sector that it cannot afford to subsidize. Ukraine is involved in a number of high-profile space projects with foreign countries, including the following:

- The Sea Launch project, a joint project with the United States, Russia, and Norway, for commercial satellite launches using Ukrainian Zenit–3SL rockets from an undersea platform at the equator in the Pacific Ocean[260]
- The Kosmotras Russian–Ukrainian joint venture to launch commercial satellites—Dnepr SLVs (converted SS–18 ICBMs)—from the Baykonur Cosmodrome in Kazakhstan[261]
- Development of updated Dnepr light-launch vehicles, equipped with an upper stage designed for high-energy orbits, to meet the demand for low-cost geostationary Earth-orbit (GEO), interplanetary, highly elliptical orbit (HEO), and other special orbit missions. Five NASA lunar missioins will use the vehicles developed in this project, a partnership between ATK/Thiokol Propulsion (United States) and Transorbital Corporation (United States).[262]

[257] "Ukraine to Strengthen Cooperation with Russia on Space Science Research," *China View* (Beijing), September 7, 2007, http://news.xinhuanet.com/english/2007-09/07/content_6680506.htm.
[258] United States, National Aeronautics and Space Administration, "International Aeronautical and Space Activities, Cooperation With Foreign Partners," http://www.hq.nasa.gov/pao/History/presrep95/coopratn.htm.
[259] United States, NASA, "International Aeronautical and Space Activities."
[260] Center for Nonproliferation Studies, "NTI: Ukraine."
[261] Center for Nonproliferation Studies, "NTI: Ukraine."
[262] Center for Nonproliferation Studies, "NTI: Ukraine."

- A joint venture between Brazil and Ukraine, under the Brasília company, with Brazil providing access to its launch base in Alcântara and Ukraine providing its rocket-launching technology for commercial space launches of rockets and satellites[263]
- Launching of Chilean satellites from Plesetsk Cosmodrome in Russia (launching began in 1995)[264]
- A cooperative project with Egypt, involving Yuzhmash and the Kharkov-based Khartron Corporation in the design and launch, using a Dnepr SLV, of the first Egyptian satellite for remote Earth sensing. Ukraine and Egypt also cooperated in developing a ground-control system for the satellite, modernizing existing data processing stations, and training Egyptian personnel.[265]
- The Kosmotras Russian–Ukrainian joint venture to launch Malaysian satellites.[266] Reportedly Malaysia also is interested in Ukraine's help building a Malysian space launch facility for launching Dnepr SLVs.[267]

Ukraine is a member of the following international space programs:

- UN Committee on Peaceful Use of Space (COPUOS)
- World Committee on Space Research (COSPAR)
- World Organization for Satellite Research of the Earth (CEOS)
- Missile Technology Control Regime (MTCR)
- International Astronautic Federation (IAF)[268]

UKRAINE'S PARTICIPATION IN INTERNATIONAL S&T

Ukraine is engaged in S&T collaborative activities with organizations and scientists from the EU and a number of countries, including Russia and the United States, and with international organizations such as the United Nations (UN), the United Nations Industrial Development Organization (UNIDO), the EU's Technical Aid to the Commonwealth of Independent States (TACIS, now part of EuropeAid) program, NATO, the World Bank, and the like. Because of

[263] ANBA Brazil-Arab News Agency (São Paulo), "Brazil-Ukraine Joint Venture Space Company Eyes Global Satellite Launch Market; To Start Operations This Year," February 21, 2007, http://www.anba.com.br/ingles/noticia.php?id=13856.
[264] "FaSAT-Alpha Microsatellite Launched," Surrey Satellite Technology Ltd Web site, September 2, 1995. http://www.sstl.co.uk/index.php?loc=27&id=131.
[265] Curtis, "Non-U.S. Space Program."
[266] "SLV Joint Venture Has Good Prospects, But Faces Obstacles," Nuclear Threat Initiative, October 13, 2001, http://www.nti.org/e_research/profiles/Ukraine/Missile/index_5523.html.
[267] "Missile Overview," Nuclear Threat Initiative, April 2007, http://www.nti.org/e_research/profiles/Ukraine/Missile/index.html.
[268] Yegorov and Voitovych, "A Science Profile," 50–51.

their intertwined history, Russia and Ukraine have extensive research partnerships. However, because of its desire for integration with the EU, Ukraine also has developed a considerable number of joint R&D projects with countries in Europe. Direct cooperation with the academies of sciences of other former Soviet countries is also on the rise.[269]

Technology Transfer

According to a 2005 study by Olena Etkova of the Bulgarian Ministry of Finance's Agency for Economic Analysis, Ukraine's total high-tech exports in 2004 ranged from 10 to 14 percent of total exports, lower than the average in Europe, which is about 20 percent of total exports. In addition, Ukraine's performance as a contributor to the global high-tech market is poor. Ukraine contributes only 0.1 percent to the global high-tech market; by contrast, Germany contributes 16 percent; Japan, 30 percent; and the United States, 40 percent.[270] In 2002, 4.7 percent of Ukraine's manufactured exports were high-tech goods, lagging behind most countries of the former Soviet Union and Eastern Europe, including Armenia, Bulgaria, Croatia, the Czech Republic, Estonia, Georgia, Hungary, Latvia, Lithuania, Poland, Romania, the Slovak Republic, and Slovenia. However, Ukraine outranks Russia and Moldova on this indicator.[271] Ukraine exports most of its high-tech goods for consumption in former Soviet states or developing countries. CIS states and developing countries consume most Ukrainian high-tech exports.

Ukrainian technology experts claim that the best opportunities for international ventures are in the areas of space; aviation and aviation engine-building; armored tank and armored vehicle engine-building; shipbuilding, including the creation of remote-controlled underwater vehicles; modern military hardware updating; optoelectronics; navigating devices; self-homing heads for ground-to-air missiles, air-to-air missiles, and artillery shells; radio-engineering control stations; sound-measuring systems for artillery reconnaissance; complex control systems; radio-communication devices; radio electronic warfare means; unmanned flying devices; aviation and missile homing systems; nanoelectronics; super-high-speed data transfer; IP telephony; light super-durable materials; heterogeneous surfaces welding; super-bright light-emitting diodes

[269] Yegorov and Voitovych, "A Science Profile," 61.
[270] Etkova, "Development of Knowledge Economy."
[271] "Science, Technology and Innovation System in Ukraine"; and World Economic Forum, "Comparison of Countries Based on High-tech Exports," http://www.insead.edu/v1/gitr/wef/main/analysis/showdatatable.cfm?vno=1.31 (accessed August 15, 2008).

(LEDs); and laser micro-engraving based on the technology for sharpening laser beams. However, despite significant R&D success in these fields, Ukraine has made no progress in introducing these products into manufacturing.[272]

According to *Jane's Sentinel Security Assessment*, in order to compete in the global arms market the Ukrainian government has made the strategic decision "to identify highly competitive Ukrainian military and dual-use technologies" for use in producing weapons for foreign customers. Ukraine hopes that the revenue generated from selling these advanced weapons will keep the country's major R&D establishments afloat and provide funds for the Ministry of Defense to purchase military equipment domestically.[273]

The following agencies deal with the export of Ukrainian technologies:

- Spetstechnoexport exports basic military-purpose technologies.
- Investments and Technologies Company exports dual-purpose technologies.
- Ukrainian Technologies exports civilian expertise.[274]

Ukraine has taken active steps to bring military and dual-use technologies to the global marketplace. For example, exporters and producers take stock of eligible technologies, based on already existing R&D, entering data on these technologies into databases. The Ukrspetsexport's database already lists more than 400 technologies, mostly military-related or dual-purpose technologies.[275]

In addition, Ukraine talks of developing a one-time declassification regime for certain military and dual-purpose technologies, so that Ukrainian exporters can transfer technologies to foreign buyers without having to apply for declassification each time a technology is sold. For example, in an effort to maximize high-technology exports available to the world market, Spetstechnoexport reviews the possible declassification of technologies annually. Ukrainian experts also have recommended simplifying the process for transfer of technology components.[276]

As Ukraine enters the global trade in technologies, it has been encountering a number of problems. The government underprices sensitive technologies or sends the technologies, and/or

[272] Badrak, "Ukraine Gambles on Technologies;" "Strategic Weapons/Section 5."
[273] "Defence Production and R&D," *Jane's Sentinel Security Assessment—Russia and the CIS*, April 4, 2005, (accessed July 23, 2007, via Intelink).
[274] Badrak, "Ukraine Gambles on Technologies."
[275] Badrak, "Ukraine Gambles on Technologies."
[276] Badrak, "Ukraine Gambles on Technologies."

the scientists who have developed them, to countries "which can inadequately use the knowledge from Ukraine." Moreover, Ukrainian scientists frequently underprice their innovations on the world market. Valentin Badrak has said that "representatives and employees of research and academic institutes [in Ukraine] regularly sell what they view as their own innovations and unique ideas for sums ranging from several hundred up to several thousand U.S. dollars to foreign companies, which later make millions on them." As Ukrainian companies are able to conform to international standards and become more adept at business, the possibilities for technology transfer will increase.[277]

Licensing

Ukraine's biggest licensees are China and Russia, but, Ukraine also has sold licenses to customers in Iran, Moldova, Poland, South Korea, and the United States.[278] Recently, some of Ukraine's more controversial licensing ventures of high technologies have been

- Ukraine's defense electronics developer Kvant Research Institute's sale of several technologies as part of the framework of a project to deliver air defense production to China;
- Ukraine's transfer of marine gas turbine expertise to China; and
- Ukraine's transfer to Iran of the expertise to build An–140 aircraft.[279]

Licensing is growing exponentially for the countries of Southeast Asia and the Middle East, traditional buyers of Ukrainian arms. Examples of these transactions include

- the transfer of Ukrainian gunpowder manufacturing technologies to Vietnam;
- the transfer of expertise in producing T–84 tanks to Malaysia and Turkey; and
- the transfer of technologies for the creation of an ion-plasma space vehicle engine to China.[280]

Ukraine also has started to import licenses, particularly from Russia and Germany. For example, Ukraine has purchased a license for manufacture of the Ka–226 helicopter from

[277] Badrak, "Ukraine Gambles on Technologies."
[278] Badrak, "Ukraine Gambles on Technologies."
[279] Badrak, "Ukraine Gambles on Technologies."
[280] Badrak, "Ukraine Gambles on Technologies."

Russia's Kamov Company, as part of the process for creating its own helicopter manufacturing capability.[281]

R&D Relations with Other Countries

Ukraine's three main international R&D partners are the EU, because of Ukraine's desire to become part of Europe; Russia, because of Ukraine's long history as the number-two developer of the Soviet Union's MIC; and the United States, because of U.S. concerns about proliferation of Ukrainian WMD scientists and expertise to dangerous international partners.

The Ministry of Education and Science (MES) of Ukraine cooperates with foreign scientific and educational establishments in developing exchange programs for faculty, graduate students, and research fellows; joint research; the organization of joint scientific conferences, symposia, and workshops; and the exchange of teachers for training, internships, and professional development. The MES has penned a number of general-purpose educational and S&T agreements with countries in Africa and the Middle East (Guinea, Egypt, Iran, Israel); Asia (China, India, North and South Korea, Turkey, Vietnam); Eastern Europe (Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Moldova, Romania, Slovak Republic, Slovenia, Yugoslavia); Europe (Austria, Belgium, Greece, Finland, France, Italy, Luxembourg, Spain, Sweden, the UK); former Soviet republics (Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Turkmenistan, Uzbekistan); Latin America (Argentina, Brazil, Cuba, Mexico); Canada; and the United States.[282]

European Union and NATO

The Sixth Framework Program (FP6) is the EU's basic mechanism for coordinating and funding European S&T programs with Ukraine. Since its 2002 agreement with the EU, Ukraine has been working with EU countries on S&T cooperation in the following research areas:

- Environmental studies and climate studies, including observation of the Earth's surface
- Biomedical research and health protection studies

[281] Badrak, "Ukraine Gambles on Technologies."
[282] Ukraine, Ministry of Education and Science, "The List of International Agreements on Cooperation in the Fields of Education and Science," http://www.education.gov.ua/pls/edu/docs/COMMON/LIST_AGREEMENS_ENG.HTML.

- Agricultural research, forestry, and fishery studies
- Industrial technologies
- Material science and metrology
- Nonnuclear power engineering
- Transport
- Information society technologies
- Social studies
- S&T policy
- Training and exchange of specialists[283]

Europe is interested in cooperating with Ukraine to gain an advantage in the competition with Japan and the United States in science-intensive technology areas.

The EU also provides technical and economic assistance to the countries of the former Soviet Union and Mongolia through the TACIS program. Specifically, TACIS supports the transfer of European technological expertise on institutional reform, including reform in the fields of food science, higher education, economics, health, private-sector development, energy and environment, production technologies, information technologies, and nuclear safety. TACIS's goal is to promote economic reform and democratization in the countries of the former Soviet Union and Mongolia. Russia, Ukraine, and the EU have established an association of technical universities. These universities will develop an integrated training system for specialists, "taking into account regional and production needs, practical trends of universities towards technoparks, development of joint standards for Ukraine and Russia." The European Community contributes to the Science and Technology Centre in Ukraine (STCU), an intergovernmental organization established by a number of donor countries and dedicated to the nonproliferation of WMD technologies and expertise. Ukraine ranks second after Russia in its cooperation under the NATO Science for Peace program in fields such as nanotechnologies, wastewater purification, computer networks, environmental monitoring, and new materials and energy sources.[284]

The German Federal Ministry of Education and Research and the Ukrainian Ministry of Education and Science officially conduct joint cooperative efforts within the framework of the

[283] Yegorov and Voitovych, "A Science Profile," 64–65.
[284] Yegorov and Voitovych, "A Science Profile," 62.

program "Cooperation with Central and East European Countries." Ukraine–Germany cooperation includes information exchange, information support for international S&T activities, conferences, workshops, fairs, training sessions, exchange programs, S&T consultancies, and joint projects in the fields of fundamental and applied research.[285]

Cooperation between Ukraine and the UK is carried out under the "Agreement Between the Government of Ukraine and Government of the United Kingdom on Cooperation in Education, Science and Culture," signed in February 1993. This cooperation has taken the form of exchange programs and joint research on S&T issues of mutual interest. The British Council at the Embassy of the United Kingdom in Ukraine facilitates this cooperation. Ukraine and the UK already have held bilateral research workshops on cryogenics; physics; information technologies and computer science (including parallel and innovative architectures, multimedia and their application in computer networks, control and digital signal processing, and medical aspects of application of information technologies); as well as the biological sciences and biotechnologies.[286]

Bilateral S&T links are on the rise between Ukraine and southern European countries, such as Greece, Italy, Portugal, and Spain. The Black Sea Economic Cooperation Organization (BSECO) for the countries of the Black Sea basin, provides one mechanism for such cooperation. Ukraine considers cooperation with Asian, African, and Latin American countries strategically important, because these markets are promising consumers for Ukraine's high-technology products.[287]

Russia

Russia is Ukraine's main competitor in the global arms market. Nonetheless, ties between Russian and Ukrainian defense production firms remain strong. According to Russia's Defense Industrial Complex State Committee, more than 400 Russian companies still rely on components from Ukrainian defense firms. Examples of joint Russian–Ukrainian outputs are the Kolchuga

[285] Yegorov and Voitovych, "A Science Profile," 61.
[286] United Kingdom, Embassy of the United Kingdom in Ukraine, British Council in Ukraine, "Science," http://www.britishcouncil.org/ukraine-science.htm.
[287] Yegorov and Voitovych, "A Science Profile," 62.

passive target detection radar, the Zoopark–2 fire control radar station, and a new countermeasures system for use against munitions with self-homing laser warheads.[288]

United States

According to agreements signed by Ukraine and the United States, as of 2008, priorities for S&T cooperation between the two countries are as follows:

- Fundamental research on key problems in the natural, social, and humanitarian sciences
- Modern energy-saving technologies for industry
- Environmental protection and development
- State-of-the-art diagnostic and treatment technologies for dangerous and communicable diseases, particularly HIV/AIDS, tuberculosis, and avian influenza
- Space exploration
- Demographic issues and development of civil society
- Prevention of proliferation of technology, pathogens, and expertise that could be used to develop biological weapons[289]

Ukraine's National Space Agency (NSAU) has approached the United States, requesting its participation in high-tech joint ventures. Ukraine hopes for U.S. assistance with its defense conversion projects, including

- telecommunication and information systems;
- modernization and development of new space carriers;
- upgrading Ukraine's Cyclone space rocket carrier;
- opening commercial space launch centers in Florida;
- production of satellites and control systems;
- production of medical equipment in Ukraine;
- development and production of drugs and vitamins in Ukraine;
- manufacture of cash registers and building of supermarkets in Ukraine;
- satellite TV broadcasting, using Ukrainian space facilities;

[288] "Defence Production and R&D."
[289] Ukraine, Ministry of Foreign Affairs, Embassy of Ukraine to the United States of America, "The Priorities of the Ukraine-U.S. Cooperation in the Spheres of Science and Technology," 2007, http://www.mfa.gov.ua/usa/en/publication/print/7049.htm.

- modernization of the Center for Maritime Satellite Navigation; and
- introduction of the INMARSAT M4 standard.[290]

CONCLUSION

The main obstacles to the development of Ukraine's S&T sector are the limited budget for financing basic and applied research in Ukraine and the need to restructure the research sector and to integrate the efforts of scientists, industry, and government; commercialize the new technologies that Ukraine's R&D sector develops; integrate Ukrainian scientists into the world scientific community; and protect intellectual property rights.[291] According to Gerson Sher, "It is in the international community's deep interest to promote such changes to ensure that Ukrainian science, with its immense potential, is fully and openly integrated into world science, technology, economic growth, and nonproliferation of weapons of mass destruction."[292]

The lack of commercialization of the products of scientific research is a major obstacle to Ukrainian technological development. According to Valentin Badrak, director of the Center for Army, Conversion and Disarmament Studies in Kiev, between 50 and 80 percent of Ukraine's production output does not "yield expected commercial results." Some experts believe that Ukraine must intensify efforts to integrate the activities of science, education, and industry and to address patenting and licensing issues through improved legislation and implementation, increased financing of science, and development of a means to monitor the needs of the users of high-tech products, both at home and abroad.[293]

Because Ukrainians lack training in the commercialization of technologies, some experts believe that buyers in the world market take advantage of Ukrainian scientists. For example, small-scale Ukrainian innovators, who do not have the funds for further R&D, have been known to sell their ideas at very early stages of development and at a low price. Badrak says the "price paid for an 'idea' seldom exceeds US$100." Ukrainian inventors also get the short end of the stick in deals involving the sale of patents, patent licenses, or licences. Badrak suggests that Ukraine should pursue technology export on the basis of the sale of patented technologies or

[290] United States, Department of State, "Ukraine: National Space Agency," Federation of American Scientists, December 7, 1999, http://www.fas.org/spp/guide/ukraine/agency/mark0125.htm (accessed June 15, 2007).
[291] Badrak, "Ukraine Gambles on Technologies."
[292] Sher, "Role of International Collaboration."
[293] Vitalii Gryga, *Issues of Using Academy Scientific Results* (Kiev: STEPS Centre of the National Academy of Sciences of Ukraine, 2004), http://www.triplehelix5.com/pdf/A302_THC5.pdf (accessed July 26, 2007).

technologies already introduced into manufacturing. Moreover, Badrak suggests "the most important trend in the technology business is not to find a market for an already available development (when it is not known, if anyone needs it at all), but to solve a technological task offered by the market."[294]

A poll of scientific department heads and researchers, conducted in 2003–4, by Vitalii Gryga of NASU's Center of Scientific and Technological Potential and Science History Studies (STEPS) revealed that the Ukrainian science community views the Ukrainian state policy for science as adverse to R&D. In support of the community's opinion, those polled cited the following issues as remaining unresolved:

- Imperfect legislation for science and innovation activity execution
- Lack of social protection for researchers and scientists
- Lack of sufficient legislation on intellectual property
- Tax issues for entrepreneurs as potential customers and users of R&D
- High cost of patenting
- Lack of consistent and significant financing for priority areas of R&D
- Dearth of laws for stimulating industrial innovation activity
- Need to reform NASU, while maintaining its status as the highest scientific state organization and the main government expert on S&T development
- Need to remove technological institutes from NASU, so that NASU continues fundamental research while institutes conduct applied research
- Need for a more accurate assessment of Ukrainian scientists' technological competence on a global scale[295]

Despite the high level of education of the Ukrainian public and the country's role as the Soviet Union's second most important R&D developer, Ukraine's economic and political turmoil since its independence in 1990 has moved support for R&D to a back burner, even though analysts note that R&D is the key to Ukraine's economic recovery and global integration. Nonetheless, Ukraine has made important steps toward bolstering its R&D potential, cultivating important technological relationships with the EU, Russia, and the United States, to overcome the many gaps in its high-technology capabilities. Given the scientific resources Ukraine had left

[294] Badrak, "Ukraine Gambles on Technologies," 27.
[295] Gryga, *Issues of Using Academy Scientific Results*.

after the breakup of the Soviet Union, the country has the potential to become a major world player in certain sectors of the S&T economy.

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APPENDIX A. TECHNOPARKS IN UKRAINE

Technology Park	Partners	Main Activities
Institute for Monocrystals Lenina Avenue, 60, Kharkov President: NASU Academician V. P. Seminozhenko Tel./Fax: (0572) 30-74-85 Email: techno@isc.kharkov.com Web site: http://www.technopark-isc.com/	National Technical University Kiev Polytechnic Institute National Center for Implementation of Branch Innovative Programs of the State Agency of Ukraine for Investments and Innovations	Research and production of new materials, purification of substances, and creation of technologies and equipment for medicine, biotechnology, electronics, laser equipment, non-linear optics, engineering, aviation, rocket and space machinery, instrument making, chemical industry, information technologies, agricultural complex; new materials, and microwave technologies.
E.O Paton Electric Welding Institute Bozhenka str. 11, Kiev President: NASU Academician B.E.Paton Tel.: (380 44) 2876779 Fax.: (380 44) 5280486 Web site: http://www.paton.kiev.ua	NASU Electric Welding Institute 36 innovative companies and organizations (state-owned, private, joint ventures), including U.S. firms Pratt & Whitney and Motorola.	Energy-efficient and resource-saving production technologies, materials and equipment for welding and compounding materials; weld depositions, coating and processing materials; special electric metallurgy; technical diagnosis and non-destructive control; agricultural machinery; welding consumables, new technology for welding live tissue; new-generation welding fluxes using metallurgical and mining waste materials; special electrometallurgy; technical diagnostics and related processes; new materials and structures; advanced information technologies, software development, software modeling.
Semiconductor Technologies and Materials, Optoelectronics and Sensor Engineering Nauki Avenue 41, Kiev President: NASU Corresponding Member V.F.Machulin Tel: 525-40-20 Email: machulin@isp.kiev.ua Web site: http://www.isp.kiev.ua/	NASU Institute of Semiconductor Physics	Manufacture and processing of semiconductor, dielectric, and electric conductor materials, sensor-based devices, machinery, and power- and resource-saving systems for technological processes in engineering, metallurgy, power, transport, aviation, missiles, space machinery, petroleum, gas, and agriculture.
Coal Machinery (Uglemash) Universitetskaya St., 36a, Donetsk President: A.N. Gumeniuk		Development of technologies and equipment for the use of recycled power resources (mine gas methane, power of mine water and air), and production wastes; technologies for preparation, mining, and processing of coal, ore, and non-ore minerals.
Institute of Technical Thermal Physics Zheliabova Street, 2a, Kiev President: NASU Academician A.A. Dolinskiy		Development of technologies and equipment for thermal physics, power engineering, energy and resource-saving thermal technologies, industrial ecology; nanotechnologies for processing gas-liquid phases, heat-mass exchange processes, and metallurgy production.

Technology Park	Partners	Main Activities
Infotech (Ukrinfotex) Druzhkovska St., 10, Kiev President: NASU Corresponding Member S.A. Dovgiy	Ukrtelecom Joint Stock Company	The latest telecommunication technologies in various branches of science and engineering, including networks, data-transfer, Internet, IP, VPN, wireless, mobile communications, fiber-optics, TV, and radio systems.
Intellectual Information Technologies Vladimirska Street, 54, Kiev		Development of technologies, systems, materials and equipment; services in the sphere of information technologies and telecommunication systems.
Kiev Politechnika (National Technical University KPI) Peremogy Avenue, 37, Kiev With a branch in Vinnitsa President: NASU Academician M.Z. Zgurovsky	National Technical University Kiev Polytechnic Institute National Center for Implementation of Branch Innovative Programs of the State Agency of Ukraine for Investments and Innovations	Cutting-edge information technologies, system analysis, local and global computer networks and systems, control and robotics, satellite navigation communication systems, micro- and nanotechnologies, satellite communications and navigation systems, new materials development, information security, and the manufacture of ecologically pure titanium.

Sources: Based on information from: Valentin Badrak, "Ukraine Gambles on Technologies," *Defense Express* (Kiev), January 1, 2003 (accessed June 22, 2007, via Eastview); Inna Gagauz, "Support for Technology-oriented Businesses in Ukraine" (paper presented at the Seventh National Congress on Government-University-Industry Relations for National Development, Isfahan, Iran, 2003), http://www.ea-sciencepark.org.ir/PDF%20Files/51.pdf; Vitalii Gryga, "Legislation Background of Technoparks Activity in Ukraine" (student paper, n.d.), http://www.csi.ensmp.fr/WebCSI/4S/download_paper/download_paper.php?paper=gryga.pdf (accessed July 25, 2007); Ukraine, State Agency of Ukraine for Investments and Innovations, "Infrastructure," http://www.in.gov.ua/index.php?lang=en&get=113 (accessed August 15, 2008); and Igor Yegorov, "Innovation Policy and Problems of Creation and Development of the National Innovation System in Ukraine" (paper presented at the Second Session of the UNECE Team of Specialists on Innovation and Competitive Policies, Geneva, February 14–15, 2008), http://www.unece.org/ceci/ppt_presentations/2008/ic/YegorovPaper.pdf (accessed August 15, 2008).

APPENDIX B. LEADING UKRAINIAN NANOTECHNOLOGY RESEARCH ORGANIZATIONS

Name	Research Focus
Donetsk Physics and Technology Institute, Donetsk	Ceramic nanomaterials
I.N. Frantsevitch Institute for Problems of Materials Science (IPMS), Kiev	Ukraine's leading institution in the field of nanotechnologies Material science and advanced technology of metal, ceramic, and composite materials Publishes the journal *Nanostrukturnoe Materialovedenie* (Nanostructure Materials Science)
Institute for Low Temperature Physics and Engineering, Kharkov	Nanosensing
Institute for Problems in Material Science, Kiev	Ceramic nanomaterials
Institute for Single Crystals, Kharkov	Nanosensing
Institute of General and Inorganic Chemistry, Kiev	Nanoprocessing
Institute of Geochemistry and Mineralogy, Kiev	Nanoprocessing
Institute of High Technologies (IOHT), Kharkov	Develops and manufactures military and dual-use technologies for export Famous for its work on a space-based Earth monitoring system Designed a life-saving (BSLaS) system to save soldiers on the battlefield, based on unspecified nanotechnologies and nanomechanics
Institute of Organic Chemistry Nanomaterials (inorganic), Kiev	Nanosensing
Institute of Physical Chemistry, Kiev	Inorganic nanomaterials
Institute of Physics, Kiev	Inorganic nanomaterials, nanoprocessing
Institute of Semiconductor Physics, Kiev	Inorganic nanomaterials, nanoprocessing In collaboration with Schott AG of Germany, exclusive producer of Zerodur
Institute of Surface Chemistry (ISC), Kiev	Technology for the production of nanomaterials, highly disperse oxides, and composites Nano-structured silica Improved production of pig embryos in vitro using nano-biocomposites through improved media for pig oocytes
Institute of Surface Chemistry (ISC), Kiev	Technology for the production of nanomaterials and highly disperse oxides Development of novel applications of nano-structured silica in medicine, biotechnology and environmental protection
Kharkov Institute of Physics and Technology, Kharkov	Inorganic nanomaterials, nanoprocessing Holds joint patents with Dr. N. Wanderka, Hahn-Meitner Institute, Berlin, Germany, and Dr. R. Forbes, University of Surrey School of Electronics, UK
Kharkov National University of Radioelectronics, Kharkov	Nanosensing

Name	Research Focus
Kiev Polytechnic Institute (KPI), Kiev	Materials science and mechanical engineering Nanocrystalline Ti and Zr oxides for determining dissolved oxygen concentration Increasing the thermal stability of the NiSi silicide film as a promising material for nanotechnology development Structural changes in iron into nanograins
V.Ye. Lashkarev Institute of Semiconductor Physics (ISP), Kiev	Interaction between electromagnetic radiation and matter, semiconductor optics and photonics Semiconductor materials science Physics of low-dimensional structures Optoelectronics and microelectronics Technologies and materials for sensor and infrared engineering
Lvov Polytechnic University (LPU), Lvov	Inorganic nanomaterials German automaker BMW was interested in some of the research conducted at the nanophysics and molecular engineering department, specifically, LPU scientists' experience using capacitors in hybrid engines
NanoFluorescent Materials Ltd (NFM), Kharkov	Semiconductor quantum dots Semiconductor core-shell nanocrystals Supplier of inorganic semiconductor fluorophores, nanodots, and nanorods for high-sensitive fluorescence analysis
National Taras Shevchenko University, Kiev	Nanosensing
F. D. Ovcharenko Institute of Biocolloidal Chemistry (IBCC), Kiev	Physics and colloid chemistry of disperse and nanosized systems Nano-biotechnologies, and hydrogel applicators with silver nanoparticles Processes of their formation and self-organization; microkinetics, and fractal properties Biocolloidal chemistry, including the investigation of cell membranes Development of physico-chemical bases for the development of bioactive and biocompatible nanomaterials and technologies for their production Colloid and biocolloidal processes for processing mineral raw materials and environment protection Physico-chemical mechanics of natural and technogeneous disperse systems and materials Biotechnological processes in medicine Biosensor technologies in medicine and environment Nanobiotechnologies
Politechnika Technological Park, Kiev	Authorized to do work in micro and nanotechnologies, considered a "sensitive technology, important in modern military business"
Precarpathian National University, Ivano-Frankovsk	Inorganic nanomaterials
Ukrainian State University of Chemical Engineering (USUCE), Dnepropetrovsk	Inorganic nanomaterials

Sources: Based on information from Valentin Badrak, "Ukraine Gambles on Technologies, *Defense Express* (Kiev), January 1, 2003 (accessed June 22, 2007, via Eastview); Science and Technology Center in Ukraine, "Nanotechnology," 2005, http://www.stcu.int/documents/publications/Current/NanoTechnology_2005.pdf; and institute Web sites.

APPENDIX C. LEADING UKRAINIAN BIOTECHNOLOGY RESEARCH ORGANIZATIONS

Name	Research Focus
Bio-Test Laboratory Ltd., Kiev	Immunoreagents (antigens, antibodies, conjugates) for pharmaceutical, biotechnology, and diagnostic companies and life science researchers Veterinary vaccines Monoclonal and polyclonal antibodies for biotechnology, diagnostic companies, and life science researchers Heat shock proteins (HSP)–based cancer and viral vaccines for medical and veterinary applications
Dnepropetrovsk Biofactory, Dnepropetrovsk	Production
Dnepropetrovsk National University, Department of Microbiology and Virology, Dnepropetrovsk	Enthomopathogenic bacteria and fungi to combat plant diseases Bacteria-enhancing phosphor and nitrogen nutrition of plants that enhance soil productivity
Donetsk National University, Donetsk	Biopreparations to combat heterobasidion annosum technology of edible fungi cultivation Wood-destroying fungi, milk curdling and thrombolytic action fermentation producers
Gromashevsky Institute of Epidemiology and Infectious Diseases (IEID), Kiev	Diagnosis, treatment, and prophylaxis of sharp intestinal infections, including cholera Infections in children (diphtheria, measles, German measles, poliomyelitis, mumps) Viral infections (AIDS, flu, viral hepatitis, meningoencephalitis) zoogenic infections (leptospirosis, rabies, anthrax) Hospital infections Possesses a state depository of patentable strains, national collection of pathogenic microorganisms, and a laboratory for quality control and safety of immune-biopreparations
Institute for the Problems of Cryobiology and Cryomedicine, Kharkov	Methodological investigations of cryoinjuries, cryoprotection, the natural integrity of biological objects exposed to low-temperature conditions, and their subsequent recovery Development of methods for the cryoprotection of biological systems at various organizational levels, and on this basis the development of cryopreservation techniques for biological entities and the means for their implementation Utilization of hypothermal conditions, cryotherapy, and the cryopreservation of biological entities to treat various diseases Cell and tissue transplantation Preparations for pre-sowing processing of seeds
Institute of Animal Breeding and Genetics (IABG), Kiev	Bioresearch
Institute of Biochemistry (IBC), Kharkov	Structure, physical-chemical properties and biological function of complex proteins and supramolecular systems Mechanisms of metabolic regulation by low molecular weight molecules (vitamins, coenzymes, peptides, metal ions etc.) Methods of production and application of biologically active preparations Medical and veterinary diagnostics Biosensors for medicine, industry, and agriculture

Name	Research Focus
Institute of Cell Biology, Lvov	Development and fostering of a vibrant research culture for cutting-edge basic and applied biomedical research and for training high-quality PhD students in cell and molecular biology, microbiology, biochemistry, genetics, immunology and biotechnology, including cell and molecular biology, microbiology, biochemistry, genetics, immunology, and biotechnology
Institute of Cell Biology and Genetic Engineering (ICBGE), Kiev	Plant cell and molecular biology Biotechnology and genomics Plant cell and genetic engineering Cell biology and structural bioinformatics Plant biophysics and radiobiology
Institute of Experimental and Clinical Veterinary Medicine, Kharkov	Avian influenza Fundamental and applied research aimed at ensuring a stable veterinary and sanitary situation in Ukraine Development of new technologies directed at immunoprophylaxis and diagnostics of infectious diseases in cattle, pigs, poultry, bees, fish, and small domestic animals on the basis of modern biotechnology Development of ecologically friendly techniques for the manufacture of animal byproducts
Institute of Molecular Biology and Genetics, Kiev	Basic and applied biomedical sciences, molecular biology, genetics and biotechnology, structural and functional genomics Proteomics and protein engineering Regulatory systems and signal transduction Bioinformatics and computational gene therapy and diagnostics
Institute of Veterinary Medicine, Kiev	Study, prognostication, and prevention of infectious and noncontagious diseases of animals Implementation of highly efficient diagnostic, treatment, and prophylactic preparations, and modern technologies ensuring the well being of animal breeding and stock replenishment in Ukraine
JSC FARMAK, Kiev	Production
R. E. Kavetsky Institute of Experimental Pathology, Oncology, and Radiology, Kiev	Cancer research: tumor-organism interactions, tumor morphology, stem cells and their role in carcino- and leukemogenesis, hereditary factors and carcinogenesis, development of antitumor vaccines Research of mechanisms of carcino- and leukemogenesis Study of biology of tumor cell Development of new methods for early and differential diagnosis of oncological diseases Possesses of a unique collection of cell cultures and tumor strains as property of the Ukrainian government
Kherson State Biological Factory, Kherson	Production
A.O. Kovalevsky Institute of Biology of the Southern Seas, Sevastopol	Biology, ecology, marine environmental protection Marine ecosystem biodiversity and dynamics Development of new biotechnologies and methods for integral coastal zone management

Name	Research Focus
Laboratory for the Synthesis of Medicines, Department of Microbiology and Virology, Odessa Mechnikov National University, Odessa	Marine microbiology Ecological biotechnology Microbe diversity and microorganisms genetic fund saving Microecology of man, immunology, antimicrobial preparations Microorganisms of plants and soil, agricultural biotechnology
Lvov Scientific Research Institute of Epidemiology and Hygiene, Lvov	Rickettsial diseases, arboviral taints, tick encephalitis, ixodic tick borrelioses, tuberculosis via antibacterial drugs, diphtheria and tetanus, iodine-deficiency diseases Health effects of heavy metals and sulfur Exogenous chemical agents in the soil Preparation of scientific and methodological bases to support policy development and implementation as well as in the drafting of legislative acts Possesses a unique collection of viruses that serve as references for testing and training, fundamental and applied research also is useful in the development of diagnostic systems
I. I. Mechnikov Ukrainian AntiPlague Research Institute (UAPRI), Odessa	Quarantine infections and other especially dangerous infections Epidemiology, epizootology, ecology, diagnosis, and prevention of especially dangerous infections Diagnosis, treatment, and prevention of diseases, such as HIV/AIDS, bacterial infections (tuberculosis, nosocomial infections, sexually transmitted diseases) and prion infections Included in the list of possible International Cooperative Centers in creating the Global Network for Monitoring and Control over biological pathogenic agents
National Center of the Veterinary Biological and Pharmaceutical Industry (VetBioPharmProm), Kiev	Production
F. D. Ovcharenko Institute of Biocolloidal Chemistry, Kiev	Physics and colloid chemistry of disperse and nanosized systems Microkinetics, and fractal properties Biocolloidal chemistry Development of physico-chemical bases for the development of bioactive and biocompatible nanomaterials and technologies for their production Colloid and biocolloidal processes for processing mineral raw materials and environment protection Physico-chemical mechanics of natural and technogeneous disperse systems and materials Biotechnological processes in medicine; biosensor technologies in medicine and environment Nanobiotechnologies
O. V. Palladin Institute of Biochemistry, Kiev	Structure, physical-chemical properties, and biological functions of complex protein and supra-molecular systems Mechanisms of metabolic regulation by biologically active substances of low-molecular weight (vitamins, coenzymes, peptides, metal ions etc.) Methods of production and practical application of biologically active preparations Medical and veterinary diagnostics Biosensors for medicine, industry and agriculture

Name	Research Focus
Scientific Production Center "Vidrodzhennia M", Odessa	Development and production of modern veterinary vaccines and diagnostic systems
State Administration for Drugs and Medical Items, Kiev	Production
Sumy State Biological Factory, Sumy	Leading manufacturer of biological products for the protection of people and animals from dangerous infectious diseases, such as, anthrax, rabies, tuberculosis, swine pest, Newcastle disease, etc. Viral vaccines, bacterial preparations, live samples and glassware preparation, and packaging
M. I. Sytenko Institute of Spine and Joint Pathology, Kharkov	Problems of diagnostics and treatment of the diseases and injuries of the spine and joints in adults and children Primary and revision endoprosthetics of the joints Application of biologically inert and biologically active materials for plastic of bone cavities and defects Treatment of axial deformations and shortened limbs in children Mini-invasive and mini-instrumented surgery of the spine Treatment of complications after traumas of the spine, pelvis and limbs Treatment of the tumors of spine, pelvis and limbs
B. Verkin Institute for Low Temperature Physics and Engineering (ILTPE), Kharkov	Electronic phenomena in conducting and superconducting systems Physics of quantum liquids, quantum and cryocrystalls Low-temperature magnetism Molecular biophysics, low-temperature physics of macromolecules Mathematical physics and mathematical analysis Geometry and topology
Veterinary Medicine (VetMedicine), Kharkov	Production
Zabolotny Institute of Microbiology and Virology (IMV), Kiev	Possesses a National Collection of Microorganisms with more than 20,000 strains used for molecular biological research and biotechnology Publishes *Microbiologichny Zhurnal* (*Microbiological Journal*) Systematics, biochemistry, genetic of microorganisms Biological activity of microorganisms Molecular biology of viruses Creation of new microbial biotechnologies for public health, agriculture, industry and environmental protection

Sources: Based on Information from Science and Technology Center in Ukraine, "Biotechnology," 2006, http://www.stcu.int/documents/publications/current/Biotechnology_Ukraine_2006.pdf (accessed July 17, 2007); and institute Web sites.

APPENDIX D. LEADING UKRAINIAN CHEMICAL RESEARCH ORGANIZATIONS

Name	Research Focus
Division of Functional Materials Chemistry, Institute for Single Crystals, Kharkov	Fluorescent materials for applications in the life sciences Organic scintillation materials for biology, medicine, environment monitoring, and physics Synthesis, investigations, and application of organic luminophores and dyes Synthesis of biologically active compounds Analytical chemistry of medicines, foodstuffs, environmental objects, functional materials, and noble metals Synthesis and investigation of optically active components for liquid-crystalline materials Synthesis and investigation of heterocycles, photoactive organic compounds, and composites Microwave and ultrasound assisted organic synthesis Investigation of molecular, crystal structure, and properties of carbocyclic, heterocyclic, coordinating and inorganic compounds, and intermolecular complexes Computational chemistry Quantum chemical simulations of reactivity, molecular and supra-molecular structure, and photo-physical properties
Institute for the Problems of Cryobiology and Cryomedicine, Kharkov	Methodological investigations of cryoinjuries, cryoprotection, the natural integrity of biological objects exposed to low-temperature conditions, and their subsequent recovery Development of methods for the cryoprotection of biological systems at various organizational levels, and on this basis the development of cryopreservation techniques for biological entities and the means for their implementation Utilization of hypothermal conditions, cryotherapy, and the cryopreservation of biological entities to treat various diseases Cell and tissue transplantation Preparations for pre-sowing processing of seeds
Institute of Biochemistry (IBC), Kharkov	Structure, physical-chemical properties, and biological function of complex proteins and supramolecular systems Mechanisms of metabolic regulation by low molecular weight molecules (vitamins, coenzymes, peptides, metal ions, etc.) Methods of production and application of biologically active preparations Medical and veterinary diagnostics Biosensors for medicine, industry and agriculture
Institute of Biocolloidal Chemistry (IBCC), Kiev	Chemresearch
Institute of Bioorganic Chemistry and Petrochemistry (IBCP), Kiev	Development of chemistry of biologically active peptides, proteins, nucleic acids, and their components Chemical models of biological processes, synthesis, and study of biological properties of new regulators to be utilized both in medicine and agriculture Scientific fundamentals and technologies for obtaining of practically useful products and materials from hydrocarbon material

Name	Research Focus
Institute of Macromolecular Chemistry (IMC), Kiev	Chemresearch
Institute of Surface Chemistry (ICS), Kiev	Medicobiological problems of surfaces Novel media for cryoprotection of reproductive cells Sorbent for removing petroleum products from water surfaces Plant protection and stimulation Hydro-gel implants for plastic surgery
Lvov Department of Institute for Physical Organic Chemistry and Coal Chemistry, Lvov	Investigation of synthesis of biosurfactants in biomedicine, agriculture, food, pharmaceutical, and cosmetic industries Development of methods of biotechnological remediation soil Biosynthesis and studying of microbial enzymes Creation and investigation of new polymeric materials Investigation of catalytic oxidation of hydrocarbon derivatives Monitoring of petroleum-contaminated water and soil
F. D. Ovcharenko Institute of Biocolloidal Chemistry, Kiev	Physics and colloid chemistry of disperse and nanosized systems Microkinetics, and fractal properties Biocolloidal chemistry Development of physico-chemical bases for the development of bioactive and biocompatible nanomaterials and technologies for their production Colloid and biocolloidal processes for processing mineral raw materials and environment protection Physico-chemical mechanics of natural and technogeneous disperse systems and materials Biotechnological processes in medicine; biosensor technologies in medicine and environment Nanobiotechnologies
Ukrainian State Chemical Technological University, Dnepropetrovsk	Extracting biologically active substances (BAS) (lecytin, pectin, etc.) Biosythesis of BAS (growth stimulators, phyto-hormones etc.) Vermin technologies Elaboration of ozone-growth-regulation, obtaining synthetic BASs

Sources: Based on information from Center for Nonproliferation Studies, "NTI: Country Overviews: Ukraine: Profile," Nuclear Threat Initiative, April 2006, http://www.nti.org/e_research/profiles/Ukraine/index.html (accessed July 13, 2007); and Ukraine, State Property Fund of Ukraine, "Chemical and Petrochemical Industry," UkraineGateway, n.d., http://www.ukraine-gateway.org.ua/gateway/gateway.nsf/webcontent/05020300 (accessed October 10, 2007).

APPENDIX E. LEADING UKRAINIAN SENSOR RESEARCH ORGANIZATIONS

Name	Research Focus
Aerotechnica Ltd., Kiev region	Development and manufacture of air traffic control (ATC, ATM), air defense (AD), air force (AF), and related products The only manufacturer of automated facilities allowed for use in ATC, in Ukraine
Arsenal, Kiev	The Soviet Union's source of infrared seekers Updated the MK–80 optical homing head with a new, more sensitive seeker Some collaboration is reported to continue between Ukraine and Russia
Elsys Electronic Systems, Poltava	Development, modernization, and full-scale production of radio electronic products, mainly microwave units in the range from 0.1 to 18GHz, for ground, shipborne, and airborne radars Air defense radar Navigation systems Cellular communication systems Medical equipment Wireless communication Low-noise microwave amplifiers, low-noise amplifiers with limiter, medium power microwave amplifiers, power microwave amplifiers (up to 50W), broadband amplifiers, limiters, attenuators Dielectric Resonator Oscillators (DROs), receiver-transmitter modules for active phased arrays, mixers, switchers, microstrip boards, and filters and adjusted filters and satellite and ground-based communication systems for use in the military, weather, air-traffic control, and civil aviation
Kvant Design Bureau, Kiev	A top-secret organization in Soviet times Design and production of targeting systems for missiles, various types of radars, and optical-electronic systems Bereh coastal radar system, capable of detecting something as small as a diver with scuba gear Bober radar system designed for protecting important installations. Kashtan-3 optoelectronic countermeasure capable of detecting laser beams of targeting systems and leading laser-guided bombs and missiles away from their targets using a false laser spot
Lvov Radio Engineering Research Institute (LRERI), Lvov	Fee-based organization providing customized R&D services for millimeter wave radars and land vehicle electronics (vetronics) Flexible and flexible-hard printed circuit boards, antenna-waveguide assemblies, radiotransparent radome, 3D antenna polarizers, millimeter-wave band twist and transreflectors using composites, carbon plastic, honeycomb fillers production engineering In the times of the Soviet Union, the Institute was the leader in creating radio systems for external-trajectory measurements and in using 3 mm wave band in radar equipment developments for various purposes.
Orion Scientific Research Institute, Kiev	Development and production of semiconductor microwave components for the Soviet military Through the U.S. NGO CRDF, has worked with Western partners on radar for use in automotive performance and safety systems using GPS, Inertial Navigation, and ORION/ATI radar systems.

Name	Research Focus
Usikov Institute for Radiophysics and Electronics of the NASU, Kharkov	Partnering with the International Research Centre for Telecommunications Transmission and Radar, a research center at Delft University of Technology in the Netherlands, as well as the National Aviation University of Ukraine in Kiev Topics unknown

Sources: Based on information from Douglas Barrie, "Russia Unveils Additional Adder Family Members," *Aviation Week & Space Technology* 157, no. 21 (November 18, 2002): 38, http://proquest.umi.com/pqdweb?index=95&did=242523211&SrchMode=1&sid=1&Fmt=3&Vinst=PROD&Vtype=PQD&RQT=309&Vname=PQD&TS=1184965883&clientId=45714 (accessed July 20, 2007); "Supporting Scientific Achievement in Ukraine," U.S. Civilian Research and Development Foundation, May 12, 2006, http://www.crdf.org/factsheets/factsheets_show.htm?doc_id=372860; and company and institute Web sites.

APPENDIX F. LEADING UKRAINIAN AVIATION RESEARCH ORGANIZATIONS

Name	Research Focus
Aircraft Repair Plant no. 410, Kiev	Aviation research
Antonov Aeronautical Scientific/Technical Complex (Antonov ASTC), Kiev	Aircraft manufacturing and services company and aviation research Particular expertise in the field of very large aircraft construction One of the best aviation design bureaus of the former Soviet Union Today occupies 40 percent of the world market for large size transportation Aircraft construction and manufacture, airfreight services, aircraft maintenance and upgrading, aerospace-related engineering support, operation of the Antonov airport, trolleybus construction and manufacture, and, since 1992, manufacture of civil aviation aircraft Designs and builds new aircraft prototypes and modifies earlier designs and provides operational and product support in order to extend the service life of existing aircraft Provides service such as basic and conversion training for flight and maintenance crews and international air charter transportation, particularly of outsize cargoes
Antonov Scientific and Production Complex Design Office, Kiev	Aviation research
Aviant Kiev Plant, Kiev	Aviation research
Buran Institute, Kiev	Aviation research, navigation equipment
Central Research Institute of Navigation and Control (TsNII NiU), Kiev	Aviation research Designs, manufactures, and implements navigation and control systems for aviation, marine, and ground transportation Computer engineering and software development producing computer operating systems, local network software, made-to-order software packages, radar-tracking systems, and communication and telecommunications transmitting and receiving equipment
Dnepropetrovsk Aggregate Plant Joint Stock Company, Dnepropetrovsk	Aviation research
ElectronPribor OJSC Joint Stock Company, Lvov	Aviation research (electronic equipment)
FED Machinebuilding Plant, Kharkov	Aviation research
Kharkov Aggregate Engineering Design Office, Kharkov	Aviation research
Kharkov Aircraft Manufacturing Plant, Kharkov	Aviation research
Kharkov Aviation Institute (KhAI), Kharkov	Large aviation research center 80 percent of specialists with higher education working in the Ukrainian aviation and space complex graduated from KhAI. Hypersonic aerodynamics, durable aviation construction, the construction of aviation and rocket engines, and control systems Close ties with industry Co-implementer of the multinational Alpha International Space Station Program and participates in scientific cooperation with companies in China, Germany, Japan, Mexico, the Netherlands, and the United States

Name	Research Focus
Ukrainian R&D Institute of Aircraft Technology (UkrNIIAT) Joint Stock Company, Kharkov	Aviation research

Sources: Based on information from GlobalSecurity.org; *Jane's All the World's Aircraft*; and institute and company Web sites.

APPENDIX G. LEADING UKRAINIAN SPACE-RELATED RESEARCH AND PRODUCTION ORGANIZATIONS

Name	Research Focus
Dnepropetrovsk State Design Institutes, Dnepropetrovsk	Engineering research and design, legal support for industry, machine design
Kharkov Electrical Equipment Plant, Kharkov	Control systems, power sources, telemetric equipment, automatic control equipment, energy consumption meters
Kiev Instrument Production Association (KievPrilad), Kiev	Design of onboard and ground control systems for launch vehicles and satellites
Kommunar Production Association, Kharkov	Onboard and ground based equipment for space complexes and their control systems
Monolith Company, Kiev	Control and guidance systems for rockets and ballistic missiles.
National Space Facilities Control and Test Center, Crimea	Spacecraft flight control, data reception from spacecraft, outer space control, space equipment testing
Obriy Company, Chernigov	Receiving, processing, and archiving data from Earth remote sensing
Pivdenne, Dnepropetrovsk	
Production Association Yugmashzavod, Dnepropetrovsk	
Pryroda State Research and Production Center, Kiev	Processing, storing, and distributing Earth remote-sensing information; research and manufacturing for the implementation of remote technologies in environmental monitoring; geological mapping
Research Institute for Radio Measurements, Kharkov	Development and production of control and data transfer systems for spacecraft
Research Institute of Radio Sets, Lvov	
Research-Technical Institute for Instrument Making, Kharkov	Space equipment design, development, and production of processing equipment and electronic appliances
Soyuz Scientific Research, and Design Institute, Kharkov	Development and construction of special and departmental telecommunications and information control systems
State Research and Engineering Center for Space Technology Certification, Dnepropetrovsk	Certification of instruments and components
Ukraine Space Enterprise (Ukrkosmos), Kiev	Satellite communications systems, including global connection from Ukraine to international information networks, and leases of satellite communications system resources to operators and single users
Ukrainian Engineering Technology Research Institute, Kiev	Technologies and facilities for production of composite materials, methods of non-destructive inspections, galvanic-chemical and coating technologies, and welding equipment

Sources: Based on information from Glenn E. Curtis, "Non-U.S. Space Programs: Ukraine Profile and Potential Contributions to Collaborative Efforts," Washington, DC, Federal Research Division, Library of Congress, February 2005.